

IN THE BEGINNING

Geoscience Features Picture Library

THE OCEANS WERE BORN from the fiery insides of a newly-formed Earth. Water vapour that escaped with gases in great volcanic eruptions eventually cooled and fell as unremitting rain over the rocks. And as it fell, the rain gathered in huge hollows in the Earth's crust, forming the first oceans, 4,000 million years ago.

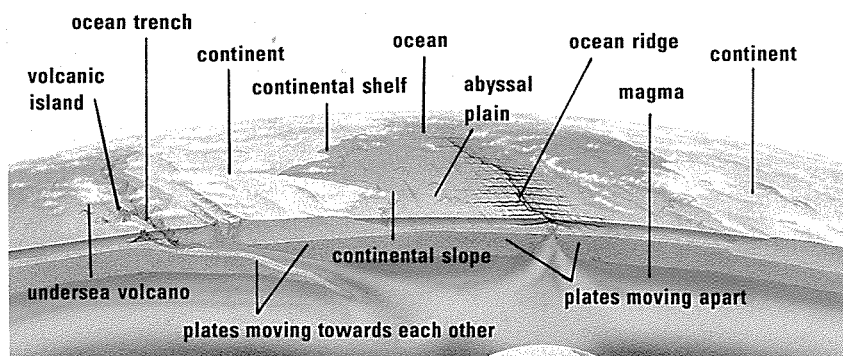
A journey to the bottom of the ocean would reveal a view of mountains, valleys and plains larger than any found on land above. When a continent enters the ocean, it continues to descend for nearly 200 metres below sea level. This is the continental shelf, whose edge marks the true boundaries of a continent.

Beyond the edge, a steep gradient marks the continental slope, which then plunges further into the

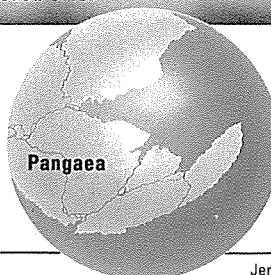
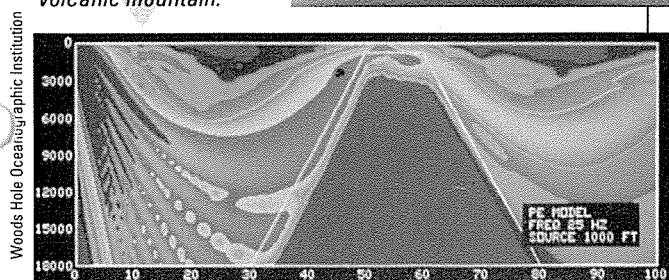
***Angry bursts** of fire and brimstone rip through a volcano – a terrifying reminder of the origins of the oceans. The newly-formed thin crust on the molten, young Earth similarly gave way to huge eruptions of hot gas from within. The water vapour that condensed fell as torrential rain, and formed the first rivers and oceans billions of years ago.*

PLATE TECTONICS

Computer graphics translate sound transmissions into a picture of an undersea mountain. It is more than 4,500m tall. A sea mount is formed by magma from beneath the crust. It solidifies and builds up over thousands of years to form a towering volcanic mountain.



The ocean bed lies on the Earth's crust. A slice through Earth shows the crust made up of plates. The movement of these plates is explained by the theory of plate tectonics.



Only one supercontinent, Pangaea, existed about 200 million years ago. As the Earth's plates shifted, parts of Pangaea separated to form the seven main land masses.

Jeremy Gower



CORAL REEFS AND VOLCANIC ISLANDS

Coral reefs often form around volcanic islands. Billions of reef-building coral lay down the framework of the reef, and skeletons of various marine organisms then fill in the gaps. Over thousands of years, as the sea level rises or the sea bed sinks under the weight of sediment,

the volcanic island may slowly submerge. However, more coral continues to grow on top of the dead coral. Only a circular group of islands – an atoll – is left on the surface. But it is still attached via the old dead coral to the sunken volcano.



Kuoni Travel

water for another 3,000 metres. After this, it starts levelling out at a much gentler incline where it is known as the continental rise.

The continental rise finally levels out at 3,700–4,000 metres when it becomes the abyssal plain. This is the floor of the ocean, the base from which all land ultimately rises.

On the move

Imagine this base as a giant jigsaw made up of seven large plates and several smaller ones. Each plate is approximately 100 km deep and floats on a bed of hot, semi-liquid rock called magma. Because of the sluggish movement of the magma below, the plates can be dragged around up to 15 cm each year. This process is explained by the theory of plate tectonics.

On the ocean floor, the edges of the plates are principally marked by a ridge of mountains or a trench.

When two plates move away from each other, magma from in-

side the Earth is spewed up to fill the gap. As it comes into contact with the cold ocean water, it solidifies to form new rocks. This process, known as seafloor spreading, slowly forces the continents apart by up to 10 cm a year.

Over millions of years, the new rock builds up to form undersea mountain ranges. These ocean ridges run along the floors of each of the major oceans, forming a continuous network.

The opposite of ocean spreading, ocean shrinking, takes place when two plates move towards each

other and collide. One plate is pushed under the other, and this forms an ocean trench.

The Marianas trench, 2,575 km east of the Philippines in the Pacific, is 11,034 metres deep – more than twice the depth of the average ocean floor. It is the deepest trench in the world.

As the two plates slowly grind towards each other, they may sometimes lock together. When they eventually break free of each other, the sudden movement is felt as an earth tremor, which may set off an earthquake.

In 1985, an earthquake that started 64 km off Mexico's Pacific coast, caused widespread damage inland and killed 7,000 people, mainly in Mexico City, which stands on unconsolidated lake sediments.

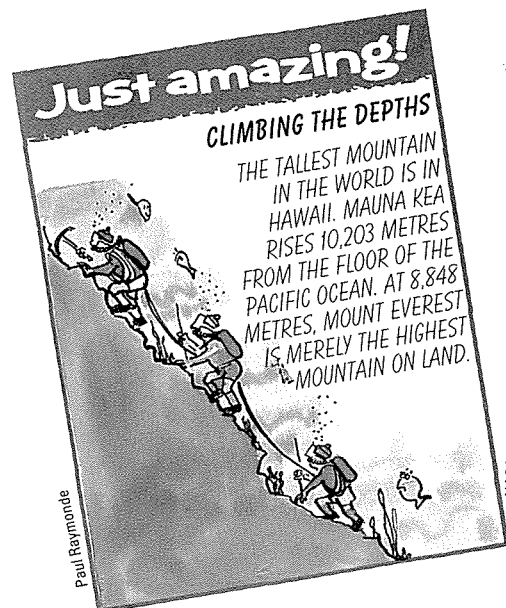
Earth, fire, water

The tremendous force and heat produced when a plate edge descends sometimes weakens the surface of the sea floor so much that magma from below is able to burst through. As a result, chains of volcanoes may form along one side of the ocean trench. Peaks of many such volcanoes emerge from the sea as volcanic islands.

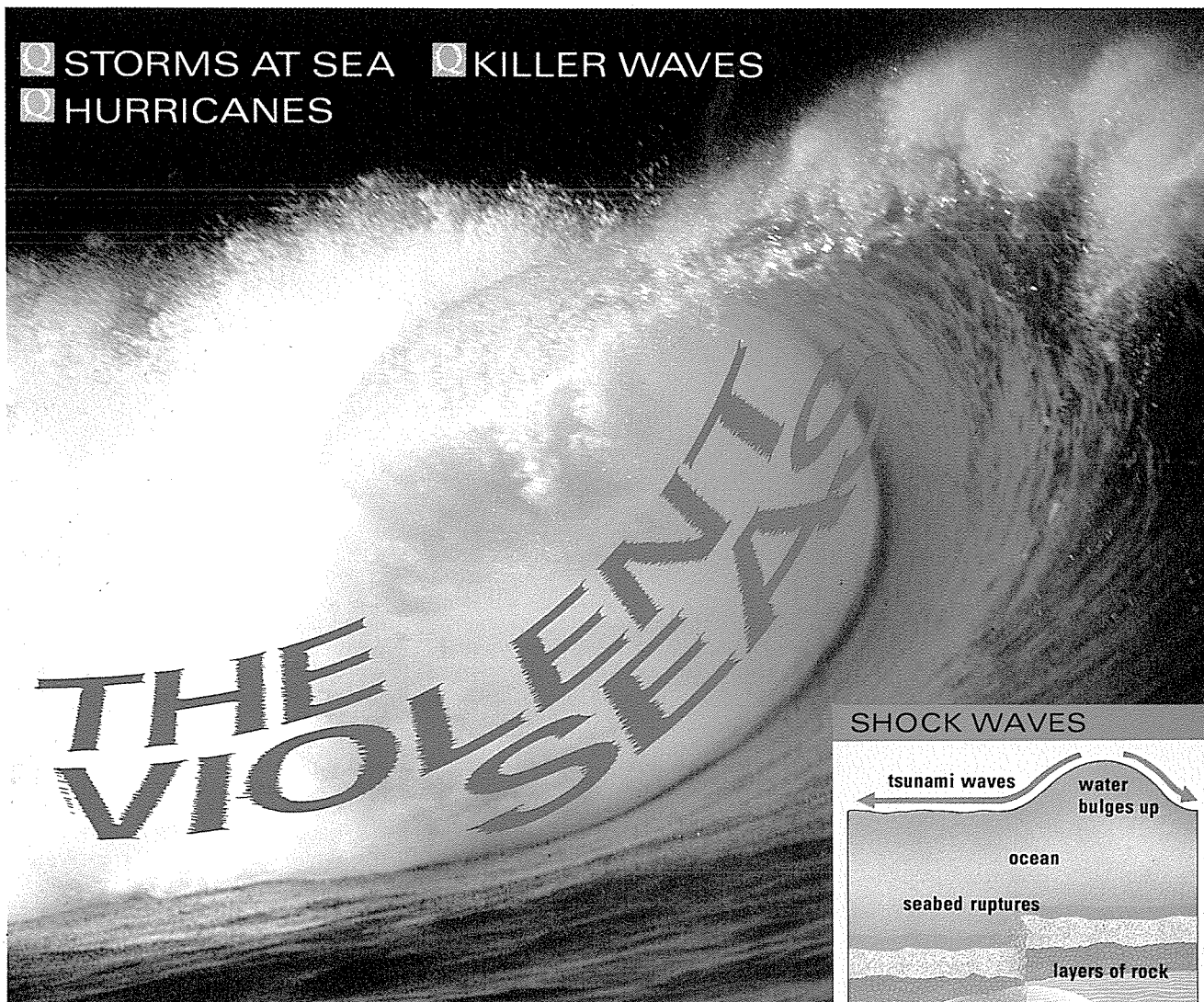
Sometimes volcanic islands are found in more unexpected places. The Hawaiian Islands, many of them active volcanoes, lie in the middle of the Pacific plate. Here, the 'hottest spot' on Earth is constantly erupting with magma. As the plate moves over the hot-spot, a chain of volcanic islands is formed.

THE WATERY PLANET

When viewed from space, one of the most striking features of the Earth is that more of its surface is covered by oceans than by land. Together, the five oceans – the Pacific, Atlantic, Indian, Arctic and Antarctic – cover just over 70 per cent of our planet. The astronaut has a similar make up – 66 per cent of his body weight is made up of water.



STORMS AT SEA KILLER WAVES HURRICANES



Planet Earth Pictures/Le Roy F Grannis

A STORM AT SEA CAN BE spectacular – seen from a safe distance. As the wind passes over the water's surface it creates waves. But if the force of the wind is strong, powerful waves are generated, gathering momentum until a barrier in their path causes them to break with full force.

Not all waves are of equal height. This is partly because the wind seldom blows at a constant speed. When the wind dies down, wave length is maintained but wave height decreases gradually. Where there are no barriers in their path, wave crests may carry over vast distances.

When waves created in different places come together, they produce a confused sea state. Boats may be completely overwhelmed by a storm at sea – getting swamped, smashed, or both, by the huge quantity of water falling on them.

The full force of a wave is not realized until it reaches the shore. As it sweeps in towards land, contact with the sea-bed slows down the lower part, but the wind keeps the top moving on. The wave becomes steeper, begins to overhang, and finally crashes down. On steep

A giant wave is a surfer's dream. But even these 'giant' waves are dwarfed by killer waves, known as tsunamis, which can reach heights of over 30 metres. When they hit land, they cause havoc and destruction.

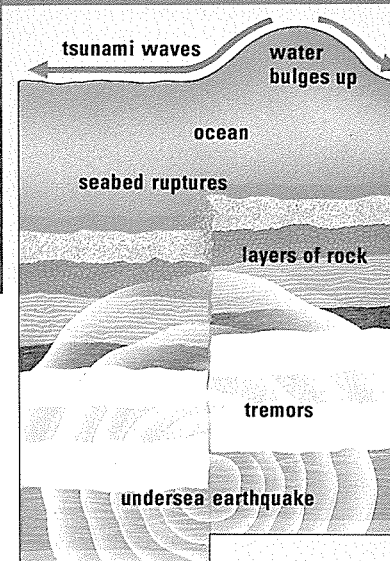
shores, waves do not have time to slow down. Suddenly, their way is barred and they smash against the rocks with tremendous force – 100 tonnes per square metre is not unusual.

Spinning destruction

Winds exceeding Force 12 (over 117 km/h) can devastate anything that lies in their path. They are known as hurricanes in the Atlantic, typhoons in the North Pacific and cyclones in the Indian Ocean and around Australia. These great storms start when scattered cloud clusters of tropical thunderstorms are gathered together into a whirling spiral by the Earth's rotation. At the centre of the spiral is a column of low pressure – the eye.

Because of the low pressure, air is sucked into the spiral with great force, resulting in violent winds. These set up huge waves at sea, which have a devastating effect.

SHOCK WAVES



Alan Sattie

Tsunamis, often wrongly called tidal waves, mostly occur in the Pacific Ocean, particularly in the 'earthquake belt' off Japan. A Tsunami Warning System, with its nerve centre at Honolulu, in the middle of the ocean, monitors seaquake activity and warns all the Pacific countries when a tsunami is imminent.

Hurricanes may persist for up to ten days, and although the path they will follow can be predicted to some extent, unexpected twists and turns are common.

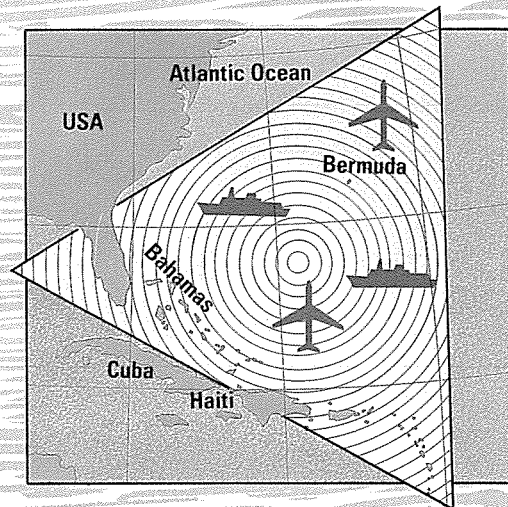
A water spout is another example of the sea being whipped up. This is rather like a liquid tornado. Warm air rising from the sea creates a central column of low pressure which draws up a swirling rising wall of water.





THE BERMUDA TRIANGLE

Known variously as the 'Triangle of Death' or 'Graveyard of the Atlantic', the Bermuda Triangle is an area off the eastern coast of the USA, around Bermuda, where more than 1,000 people and several ships and aircraft have been mysteriously sucked into oblivion. According to a popular theory, extra-terrestrial activity – or even the Lost City of Atlantis – is responsible for these losses. But more scrupulous research suggests that most of the accidents had natural causes.



When a low pressure system – depression – passes quickly across the sea, the water level suddenly drops, then rises. A great swell is created, known as a storm surge, which can flood huge areas as it hits land.

Tsunamis

Just as terrifying as rough seas, are tsunamis, caused by earthquakes and volcanic eruptions in the ocean. Small earthquakes occur along the ocean ridges, where the Earth's crust is thin and hot. The largest ones are along the lines of collision of the plates.

The quake lifts the ocean floor, which buckles and collapses, and the shock tremors suddenly move

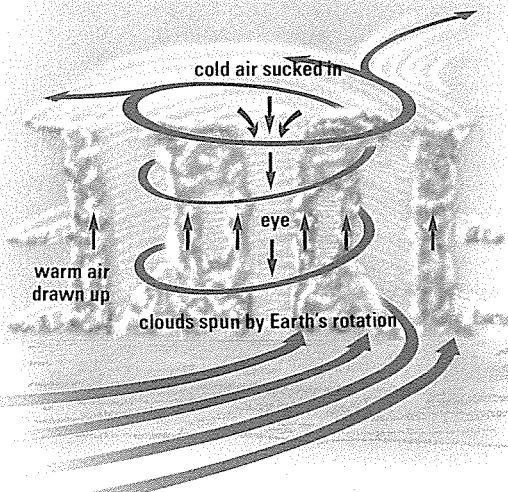
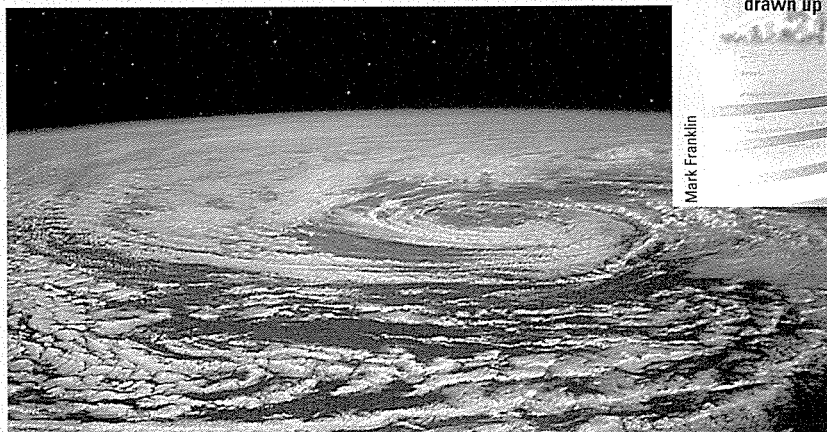
the whole mass of water above, right from the ocean floor to the surface. As the tremors radiate outwards, the tsunami sweeps across the ocean at terrifying speeds of up to 720 km/h.

At first, tsunamis are very small and may not be noticed in the open sea. However, as they come to shallower water, they are slowed down by the drag of the sea-bed and the wave builds into a vast wall of water with an awesome power for destruction. They hit the coastline with tremendous force. Boats are thrown high up on the shore, land is filled with sea water and houses destroyed. The highest, recent tsunami occurred off south-west Alaska in 1964 and reached 67 metres.

After a cyclone, life returns to normal in Hong Kong. The effects can be devastating, not just in terms of damage to property but in loss of life. A cyclone in Bangladesh in 1970 caused one million deaths.

Planet Earth Pictures Ian Kent

THE EYE OF THE HURRICANE



The eye of a hurricane can be seen clearly from space. Around the still, quiet centre the most damage is caused as warm air spins upwards in a spiral (above). Storm clouds form while the low pressure at the centre sucks in cooler, heavier air.

A place in the UNIVERSE

■ THE MILKY WAY ■ PLANET OF LIFE ■ METEOR BOMBARDMENTS

IN THE VASTNESS OF SPACE, lost among the countless stars, an unremarkable planet spins around its own star. One fact makes this particular planet special above all others – it is our home, Earth.

The star it revolves around is the Sun, and together with the eight other planets – Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto – and their moons, they form the Solar System.

But the Sun is only one of billions of stars that go to form yet another grouping, a galaxy. Our Galaxy, the Milky Way, consists of about 100,000 million stars. Many of these stars may also be circled by planets, some of which may perhaps have life on them.

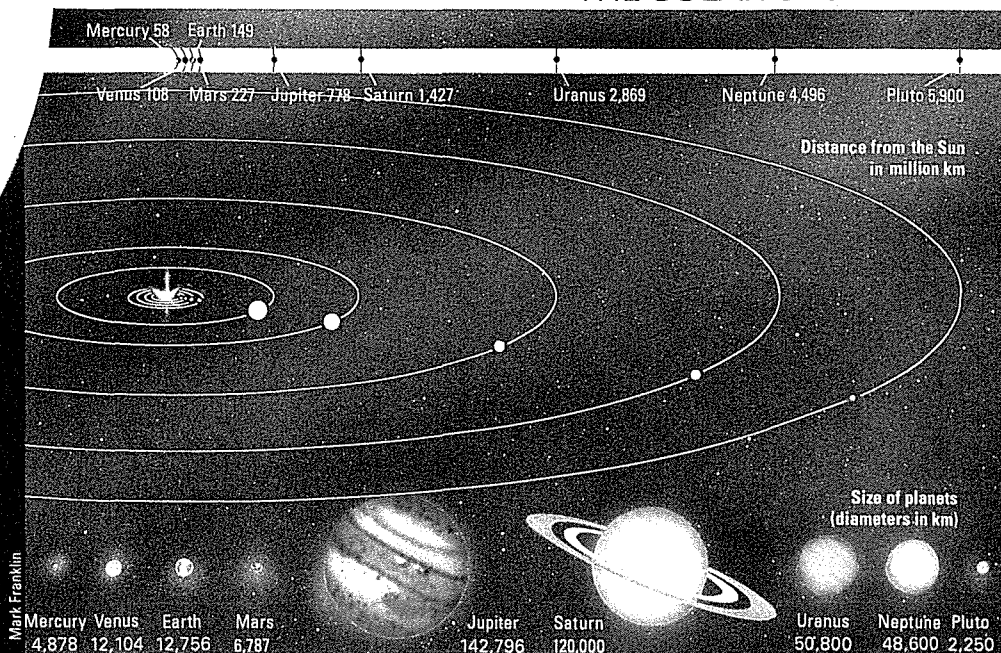
● Incredible distances

Galaxies come in different shapes and sizes. They may be spiral or elliptical, or have no clearly defined

shape at all. The Milky Way is a spiral galaxy, thick in the centre and tapering off to the sides, rather like a gramophone record. Our solar system lies about two-thirds away from the centre.

Earth orbits the Sun and spins in the vastness of space, among the brilliant star systems. These immense systems are called galaxies and they are the building blocks of the Universe. Our own Galaxy, the Milky Way, is one among billions in the Universe.

THE SOLAR SYSTEM

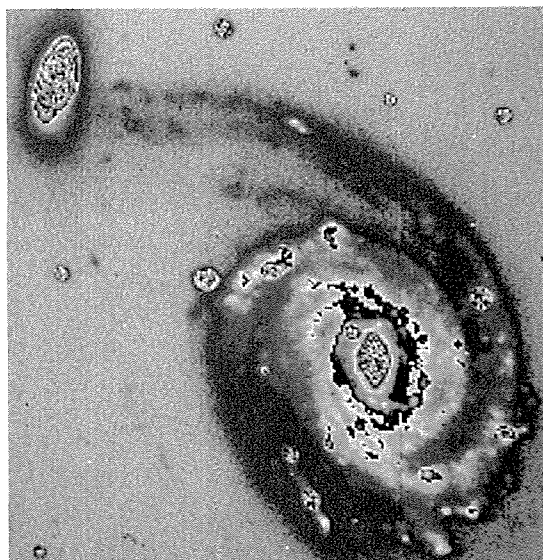


From edge to edge, the Milky Way measures 100,000 light years. Distances in space are measured in light years. This means, it would take a beam of light 100,000 years to travel from one edge of the galaxy to the other.

Light travels at 300,000 km/s — the fastest speed we know of — and a light year is the distance a beam of light would travel in that time.

meteors of every size that constantly bombarded it from space.

Slowly, the topmost layer of the Earth cooled and hardened to become a thin, solid crust. At the same time, hot, molten rocks from inside the planet continued to well up to the surface through numerous cracks and volcanoes. As they did so, this material set free gases, including water vapour, that



Royal Greenwich Observatory SPI

Two galaxies in orbit around one another. The use of false colour shows clearly the larger, spiral galaxy and a smaller elliptical one. In the arms of the spiral galaxy are vast quantities of dust and gases, from which new stars are continually being formed. All the stars in a galaxy revolve around its centre. The Sun moves at 250 km/s, but it would take around 250 million years to complete an orbit.

Since there are at least another 100 billion galaxies in the Universe, this gives some idea of the almost unimaginable scale of our ultimate place in space.

Baptism of fire

Third world out from the Sun at an average distance of 150 million km, Earth measures just 12,756 km across and has a solitary moon. It receives just enough light and heat to make it suitable for life. Except at the poles, and on high mountains, the temperature is such that liquid water can exist anywhere on the surface — a vital fact since it was in the oceans of the young Earth that life began.

Just after the Sun formed, about five billion years ago, it was surrounded by a great spinning pancake of gas and dust. Over the next few hundred million years, the loose material in this wide, rotating disc gradually lumped together to make the nine planets of the Solar System, along with a host of smaller objects like the various moons and asteroids.

Worlds, including the Earth, that formed fairly close to the Sun, built up mainly from rocks and metal. It was too warm for them to hold on to large amounts of lighter substances such as hydrogen and helium.

At first, the Earth may have glowed orange-red, like a bright coal fire. It was heated intensely, both by the break-up of radioactive elements inside, and also by

gathered around the Earth as a primitive atmosphere — a protective blanket against space.

The emergence of life

At some stage, it seems that a thick 'soup' of chemicals steadily built up in the Earth's newly-formed ocean, from gases washed out of the atmosphere. Injected with energy by bolts of lightning and ultraviolet rays from the Sun, some of these chemicals became more and more complicated. Eventually, at least one of them started making copies

Just amazing!

QUICK TRIP?

THE MILKY WAY IS UNLIKELY TO BECOME A POPULAR HOLIDAY DESTINATION. IF YOU DROVE A CAR FROM EARTH AT ABOUT 160 KMI/H, IT WOULD TAKE ABOUT 221,000 MILLION YEARS TO REACH THE CENTRE OF THE MILKY WAY.



Paul Raymond

of itself. From this amazing 'duplicating' substance, about three and a half billion years ago, the first living things developed.

The dynamic Earth

Powerful forces have shaped the Earth — and those same forces are still at work in the world today. Wind and rain scour away rock, rivers carve valleys and canyons, and ocean waves pound against shorelines, eroding their shape all around the globe.

Yet even as old features on the surface are worn away, new ones slowly emerge to take their place. Mountain ranges are formed by these powerful forces, as are oceans and continents, which drift and change in appearance over millions of years. Slowly but surely, the planet Earth is constantly changing.

DEATH OF THE DINOSAURS

Sixty-five million years ago, the dinosaurs became extinct. No one knows for sure why it happened. Some scientists believe an asteroid smashed into Earth, hurling millions of tons of dust into the air. For several months, this dust blocked out much of the Sun's light and heat, making it too cold for the dinosaurs to survive. Today, only huge meteorite craters and the Giant Iguana, a distant cousin of the dinosaurs, remain as mute relics of this prehistoric mystery.



K. Wothe/Bruce Coleman Ltd.

E.D. McKee/USGS



THE DRUGS MENACE

ORIGINS

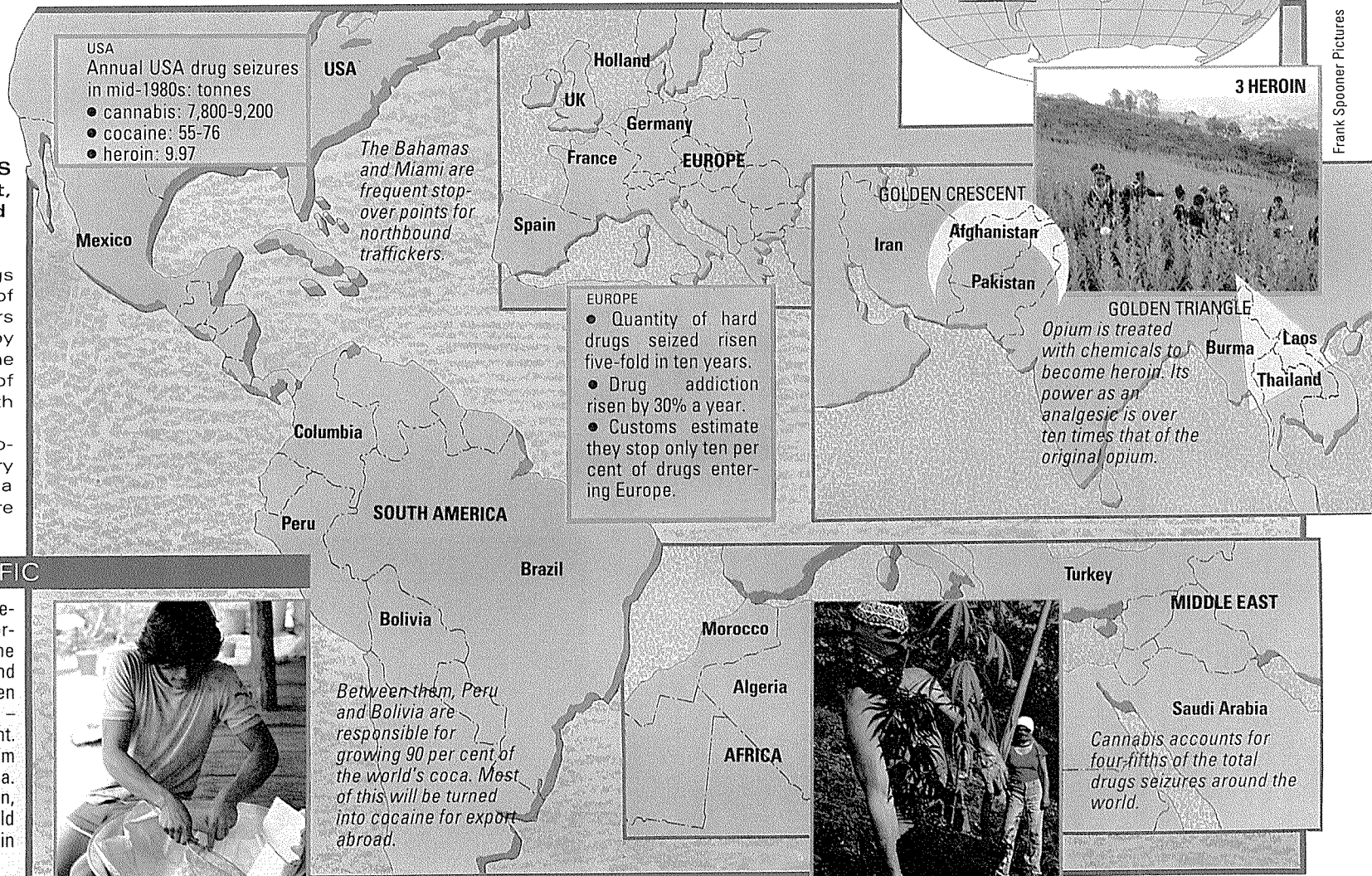
THE HEROIN TRAIL

THE 'DUTY MEN'

WALKING INTO THE CUSTOMS area of an international airport, a man suddenly keels over and dies. The cause of death – a lethal overdose of cocaine.

Swallowing small polythene bags of cocaine or heroin is just one of the extreme lengths drug smugglers go to in order to avoid detection by customs officers or police. The knowledge that a leak in just one of those bags could cause their death does not deter the drug carriers.

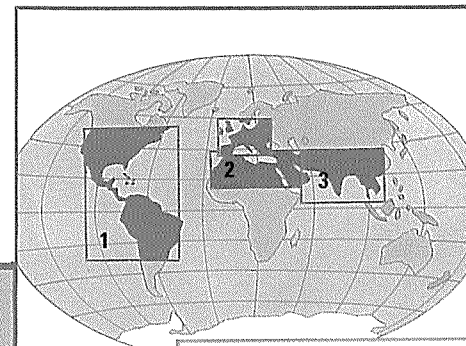
South America is the major producer of cocaine. In the hot dry areas of Peru, Bolivia and Colombia the leaves of the coca plant are



Hutchison Library



Frank Spooner Pictures



Mark Franklin

Frank Spooner Pictures

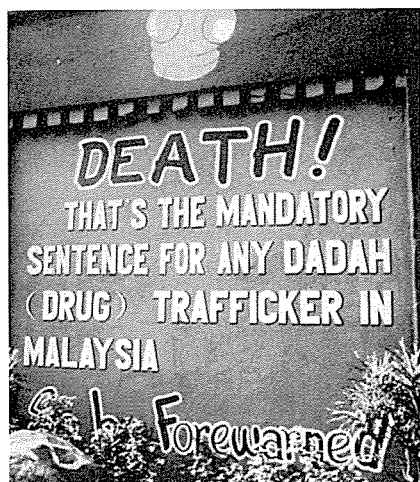


picked and processed in laboratories hidden in the jungle. Each coca leaf contains roughly one per cent cocaine. When the leaves are treated with chemicals they form a paste and, eventually, a fine white powder. The cocaine is exported around the world, to be used as it is or to be refined a stage further. Using a heat source and baking powder, a higher degree of purity is extracted from the cocaine to produce the drug known as 'crack'.

The hemp plant from which cannabis is made, also thrives in South America as well as in Northern Africa, where it is produced for smuggling abroad. The plant is related to nettles and hops. Tetrahydrocannabinol, a mild hallucinogen, is found in all parts of the hemp plant except the seed.

Resin is found in the tips of the shoots and flowers, and is scraped off and sold as hashish. The whole plant can be pressed into blocks to produce marijuana.

Dadah spells death in Malaysia – as the writing on the wall of a Kuala Lumpur prison warns. Inside drug users and smugglers await execution.



Associated Press

Heroin is derived from the opium poppy. Below the petals of the poppy flower is a seed pod that produces a juice, which is harvested as opium. Despite frequent raids to destroy the crops, farmers in the main opium growing areas are unwilling to relinquish the poppy. On average, they earn 30 times more from poppy production than they would from wheat.

The raw opium is transported to processing centres where it is converted into heroin. Since heroin is light, compact and easy to hide, smugglers have little trouble in transporting it to the big cities and from there to international airports.

A more recent arrival on the drugs scene is a tablet called Ecstasy. This is a synthetic drug made up from amphetamine powder by a chemist. Either the tablets are processed in secret laboratories abroad and smuggled in, or the powder itself is imported and made into Ecstasy tablets here.

Busting the barons

Drug smuggling has become big business. The men who operate smuggling rings – the drug barons – are so rich and powerful they are rarely caught. They pay others to take risks for them, and corruption and murder have become a way of life. Even their own employees are terrorized. In 1985, 40 workers in Peru were massacred because they refused to obey orders.

Big smuggling operations can involve hundreds of people in several different countries. In the UK, the National Drugs Intelligence Unit is staffed by police officers and by

Trained sniffer dogs are now a vital part of Southern US police forces, as they try to stem the massive tide of drugs entering from South American countries such as Colombia.



Rob Nelson/Picture Group/Colorific

Just amazing!

CASTOR OIL KILLER

RICIN, MADE FROM THE CASTOR OIL PLANT, IS ONE OF THE MOST TOXIC SUBSTANCES KNOWN TO MAN. JUST ONE FIFTY-THOUSANDTH OF A GRAMME IS FATAL – AN AMOUNT INVISIBLE TO THE HUMAN EYE.



Paul Raymond

Customs and Excise.

The police may keep a suspect under surveillance for months at a time, recording his or her actions on concealed cameras. When the suspect travels abroad, his or her suitcase may be marked with an ink visible only under ultraviolet light. On return to the UK, the case will be pulled out and a sniffer dog set loose on it to seek out any narcotics.

On the alert

Officers are aware of most of the usual – and unusual – hiding places, – inside bottles, statues, secret compartments in luggage, in food and even alongside dead bodies coming home for burial. These officers are quick to notice any containers that have been tampered with – new seams, traces of glue – or that are too heavy or too light to be carrying their usual contents.

One officer was alerted when a chess set, apparently made of onyx, was easily scratched. When handled, the items had a waxy feel. It turned out that each piece had been moulded from 90 per cent pure cocaine paste.

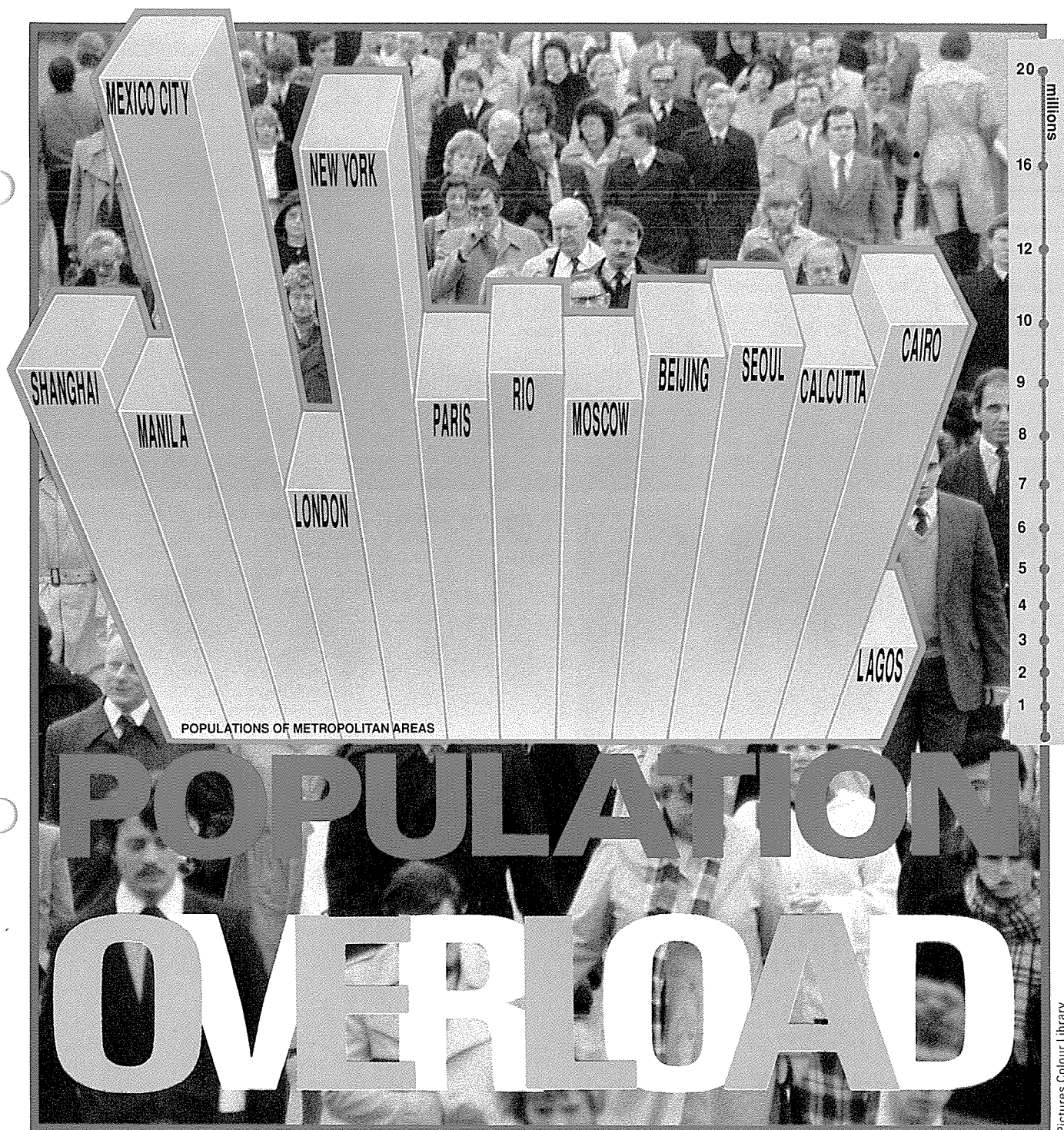
At ferry ports, a suspect car may well be stripped apart before any drugs are found. Cannabis from Northern Africa is often brought up through Spain and France, concealed in the petrol tank of a car. A spectroscope, based on fibre optics, enables officers to peer round corners inside the tank.

Looking to the future

The number of drug seizures by police and customs increased several times over in the late 1980s. Unfortunately, so too has the quantity that reaches the street.

Police enforcement alone is not enough to solve the drugs problem. Individual communities must face up to the dangers of drug abuse. In the end the solution relies upon a society in which everyone says 'No' to drugs.





POPULATION OVERLOAD

Pictures Colour Library

THE DENSEST CITIES

RURAL MIGRATION

SHANTY TOWNS

ONE BABY IS BORN somewhere in the world each second. Even allowing for the death rate, this adds millions to the global population each year. In 1987, it passed 5 billion, and by the middle of the next century, it is expected to have doubled.

China is the first country in the world where the population has topped the one billion mark. This has led to a state-controlled policy

of one child per couple. India has the world's second largest population – more than 700 million people.

But in many Western nations, the rise in population has started to level off. Even so, cities throughout Europe and North America are affected by serious overcrowding problems.

Unemployment, poverty and crime in grim ghettos, where buildings have been allowed to fall apart, contrast starkly with the luxurious lifestyles of the wealthier districts.

In developing nations, the problems are in danger of becoming insurmountable. Large numbers of rural dwellers migrate to the industrial centres in search of work. The result is an almost uncontrollable growth of the cities.

Mexico City, with nearly 20 million people (in the diagram) – and a UN projection of 31 million by the year 2000 – weighs in as the globe's most populous city.

Already, overcrowded cities, such as Bombay and Mexico City, are straining to cope with the influx of men, women and children arriving from the surrounding countryside in search of work.

Crumbling cities

By the year 2025, the cities of the Third World will be home to four billion people – four times the level of the mid 1980s. Even now, cities such as São Paulo in Brazil have traffic jams that last throughout the 12 hours of the working day, adding

dense exhaust fumes to the already polluted atmosphere.

As the quality of urban life declines, those people who can afford to, move out of the city. London, for instance has lost a fifth of its population over the last 40 years.

Small rural villages that once were well away from the fringes of the city grew as the demand for housing in them increased. In time, some may become mere suburbs of a sprawling urban area, or 'dormitory' towns, whose inhabitants commute to the city for work.

Shanty towns

Meanwhile, in the inner cities, old housing is often left to decay. Many run-down terraces were demolished in the 1960s to make way for tower blocks. But, untended, they too quickly became slums.

For the young people who have



Gamma/Frank Spooner Pictures

Irrigation projects in developing countries make once barren land arable. This provides work and food for people who would otherwise pour into already overcrowded cities.

Sally & Richard Greenhill

of any waste material – corrugated iron, empty oil drums, pieces of timber, or even cardboard. Gradually, a large community of shanties spreads out in a jumbled mass around the city.

With no fresh water supply or sewage system, the shanty town is a breeding ground for disease. Some city authorities, acknowledging the city's dependence on the

GIRLS FOR JOY



China has a growth rate of one and a half per cent each year, and, with a total of over a billion people, is the most populous country in the world. A strict birth control programme is in force restricting each couple to one child only. However, centuries old traditions mean that female babies are not very welcome. To avert a tragic fate, posters advertise the pleasure of having a girl child.



Rex Features

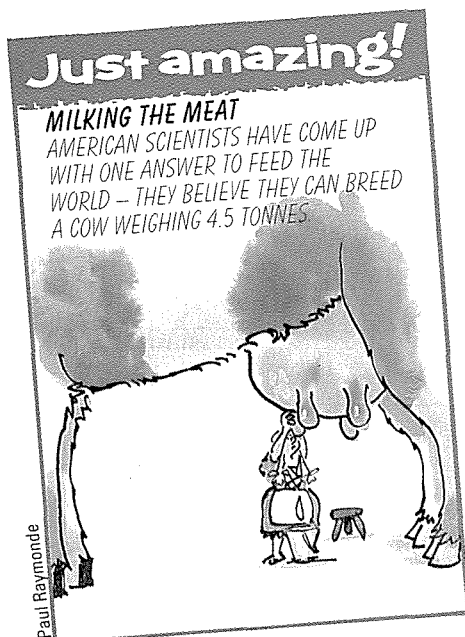
Shanty dwellers on the outskirts of prosperous cities live in the most basic shelters and make the best of what comes to hand.

workers from the shanty towns, are at least trying to help the destitute dwellers by supplying some basic amenities. Fresh water is piped into new areas where settlers arrive. Banks of building materials and advice centres are also set up so that people can make better and safer homes for themselves.

grown in the restrictive poverty of a rural village, the big cities are like a liberating magnet. They offer the chance of a job, a higher standard of living, and such luxuries as electricity, piped water and shops.

But the newcomers often have no money with which to buy or rent a home. The alternative is to sleep on the pavement or build their own simple shelter on the outskirts of the city. This is how shanty towns have developed.

A shanty is a home constructed



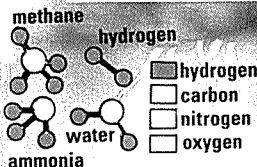
4 BILLION YEARS AGO

ONE SINGLE MICROSCOPIC living cell, less than a thousandth of a millimetre across, is the ancestor of all life on Earth, from the minutest plant forms, living as green scum on the surface of water, to the largest whales in the depths of the oceans.

This first live forebear of all living things, including Man himself, was formed by chance, probably over 3,500 million years ago.

Scientists have shown that the building blocks of life — carbon-containing organic molecules — existed on Earth, and in space, soon after the planet's formation 4,600 million years ago. They were in the gases that made up Earth's atmosphere, in the outpourings of volcanic eruptions, in the meteorites that pounded the young planet — and even in the dust of space itself.

Frank Kemmard



1. GASES IN EARLY ATMOSPHERE

Before life appeared on Earth, the atmosphere contained lots of simple chemicals such as methane, hydrogen, ammonia and water.

3. THE FIRST STEPS TOWARDS LIFE

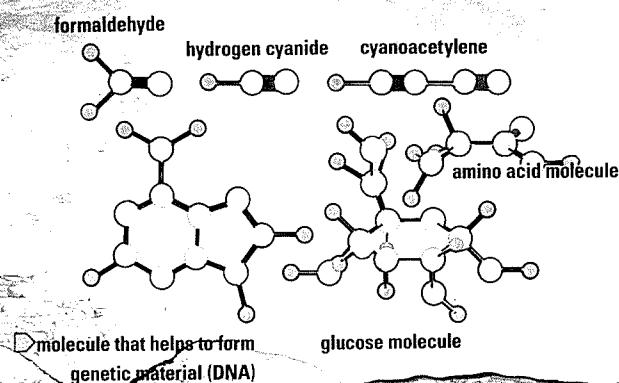
More chemical reactions took place in the ocean. Sugar molecules joined together in chains to form starches and cellulose. Even more important, simple amino acids joined

together to form simple proteins. The biggest step of all occurred when sugars and nitrogen compounds joined together to form DNA, the structure that transmits information from one generation to the next.



2. THE PRIMEVAL SOUP

Sunlight and lightning caused these chemicals to react together and form larger molecules that collected in the oceans of the young Earth.

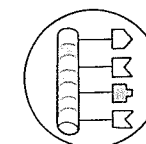
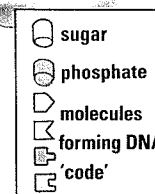


chain of sugar molecules

amino acid chain forming protein molecule

genetic material

strands of DNA



double helix of DNA

double helix unzips and replicates when cells divide



Space probes by the US and the former Soviet Union have confirmed that carbon molecules exist in the icy bodies and tails of comets, such as Halley's comet, which periodically pass close to Earth. Astronomers have identified 75 different interstellar complex molecules that have come into being in the star-forming clouds of space.

Living cells need protein molecules to form their structure, and DNA (deoxyribonucleic acid) molecules to hold information on how to develop. Both proteins and DNA are formed from other molecules, called amino acids and bases. These consist of even simpler molecules.

The odds against the correct combinations coming together by chance are enormous. Yet somehow, within the Earth's first five thousand million years, they did.

containing complex molecules such as amino acids — pierced the unresisting atmosphere and plummeted to Earth. Lava and hot gases poured out of volcanic fissures and spewed violently forth from eruptions, creating hot-spots in the atmosphere, and adding more gases to its composition.

Single cell life

Triggered by the energy from these violent natural events, the molecules in the primeval soup joined up to form complex chains. So a few hundred million years after the Earth's formation, all the components of living cells were present in the ocean and it was only a matter of time before they were organized into cells. These came into being when various fats and proteins joined together to form an outer

Fossilized micro-organisms were discovered locked into the 3,800 million year-old Isua rocks of Greenland. Scientists have also discovered colonies of fossilized blue-green algae cells in the Warrawoona rocks of Western Australia. Using electron microscopes and radiometric techniques, they have dated these to 3,500 million years.

Peter Parks Oxford Scientific Films

Lightning bolts from electrical storms bombarded the Earth and its watery surface, where shallow pools lay rich with organic molecules — a warm soup of potential life. Massive doses of ultraviolet radiation from the sun poured down into the atmosphere and on to the surface, as yet unprotected by oxygen and an ozone layer. Great numbers of meteorites — some probably

membrane. This separated the contents of the cell from the water it floated in.

For over 2,000 million years, cells remained tiny and primitive, each one hardly a thousandth of a millimetre in diameter. The first living cell split into two, each containing the DNA information necessary for further development. Two became four, and four became eight. Eventually those cells lived in teeming accumulations, millions to the cubic centimetre.

Cell mutations

As these cells reproduced, slight changes or mutations occurred in them. Sometimes these chance mutations were favourable and they helped the cell survive, often in conditions different from those in which the parent cell lived. Some cells eventually mutated into a life form that contained chlorophyll, the substance that makes plants green. With the assistance of chlorophyll, these cells started to make sugars using the energy of sunlight.

The sunlight-using cells needed hydrogen for energy conversion. They obtained it by splitting water molecules into their separate hydrogen and oxygen components. The cells used the hydrogen and released the oxygen as waste.

DNA — CREATING LIFE



Sio Photo

The scientific world ridiculed the first researchers who claimed that life sprung from organic compounds created when ultraviolet radiation or lightning struck the Earth's atmosphere. Then an American, Stanley Miller, proved the theory correct. He directed electrical charges through a mixture of methane and ammonia gases. Inside a week he had produced a tar-like ooze containing amino acids and other organic molecules. Later experiments, with ultraviolet light, heat, and even sonic booms, in a variety of gas mixtures, had similar results. Nearly all the amino acids and DNA bases necessary for cell life have been created in experiments mimicking conditions on the primeval planet.

Great matted masses of these oxygen-releasing cells lived in warm, shallow seas. After hundreds of millions of years, oxygen built up into a significant ingredient in the Earth's atmosphere.

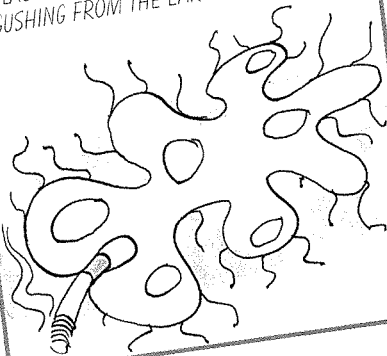
A new type of cell began to develop about 1,400 million years ago. Dependent on oxygen, this new cell was larger and much more complex. It had a special nucleus for its DNA, and had at least a thousand times as much as earlier, more primitive cells. Called a eukaryote, which means true nucleus, the new cell developed the ability to join up with other cells and share genetic information, so that their offspring had a much larger fund of genetic possibilities.

Eukaryotes also became capable of forming multi-celled organisms, in which the individual cells have particular tasks. Nearly all life in today's world is formed of eukaryote cells. The first fossils of multicellular life forms are 750 million years old.

Just amazing!

LIFE-GIVING SMOKERS?

IN THE WORLD'S DEEPEST OCEANS, BACTERIA FEED ON MINERALS SUPPLIED BY 'BLACK SMOKERS' — SUPERHEATED WATER GUSHING FROM THE EARTH'S CRUST.



Paul Raymond



BEGINNINGS

INVERTEBRATES

FISH

AMPHIBIANS

AGE OF MAN

BIRDS

MAMMALS

REPTILES



honey bee



cassidulus
salenia



cephalopod



mollusc



brachiopod



coral



millipede



eurypterid



nautiloid



trilobite



spriggina



salmon



portheus



aspidorhynchus



dapedius



palaeoniscus



pleuracanthus



cladoselache



birkenia



tree frog



newt



salamander



frog



seymouria



diplovertebron



ichthyostega

tertiary
period

65 *

cretaceous
period

135 *

jurassic
period

195 *

triassic
period

225 *

permian
period

280 *

carboniferous
period

340 *

devonian
period

395 *

silurian
period

430 *

ordovician
period

500 *

cambrian
period

570 *

precambrian
period

4000 *

*million years ago



flamingo



ichthyornis



archaeopteryx



mammoth



delfatheridium



triconodon



rattlesnake



carnosaur



diplodocus



placodon



dimetrodon

GEOLOGICAL TIME

The geological eras and their age in millions of years is shown on the main stem. As conditions changed, whole new groups of animals evolved, branched off the main stem of life and so gave rise to the diverse animal life that we now share the world with.

IN THE LONG, SLOW HISTORY of life's development on Earth, Man is so recent as to seem a mere footnote.

If the history of the world were a feature film, Man would make an appearance just as the words 'The End' were appearing on screen.

From about 4 billion years ago,

microscopic, primitive single cells, called prokaryotes, held sway in the Earth's oceans. Larger, more complex eukaryotes began to appear 1.45 billion years ago as the oxygen level of the atmosphere built up. One billion years ago, the oxygen level was around six per cent of what it is now: 400 million years

later, it had reached 50 per cent. Meanwhile, evolution accelerated.

Fossils from South Australia's Ediacara Hills show that by 670 million years ago, there were a number of soft-bodied creatures living in the oceans that we would recognize today. They included jellyfish, worms and sea-pens. As the weird and wonderful variety of life beneath the sea multiplied, some forms began to prey on others. As a result, new adaptations, with protective hard shells to ward off voracious neighbours, emerged over millions of years.

Another major survival skill was the ability to move. There were crawlers such as the woodlouse-shaped trilobites, sliders such as snails, walkers such as starfish, jet-propelled squirts such as the tentacled, shell-protected cephalopods, and swimmers.

The first fish appeared at some time between 440 and 395 million years ago. They were very primitive, jawless creatures that nosed, heavy-headed, along the sea-bed. They were also the first creatures with real backbones.

When fierce predatory fish with proper jaws and teeth evolved in the next 50 or 60 million years, they devoured the jawless fish, though some remain as lampreys.

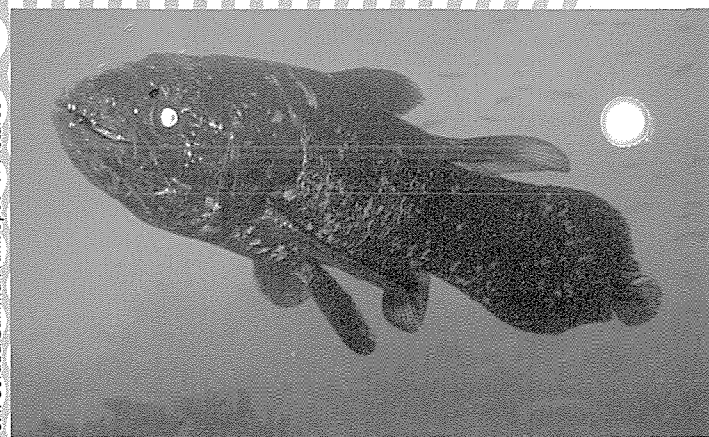
Chris Forsey





REDISCOVERED PREHISTORIC FISH

J. I. Geraud/Gamma/Frank Spooner Pictures



The most advanced of species, Man has had to adapt to survive in his environment. Bushmen in the African desert, where food and drink is scarce, can smell out water. The skin over their stomachs can expand so that they can eat several days' worth of food at a time when they finally make a kill. They are said to communicate telepathically.

The coelacanth, a fish that preceded the amphibians, dates back almost 400 million years. Scientists believed it had been extinct for about 60 million years. But in 1938, a coelacanth was found in the Indian Ocean. Modern coelacanths live 200 metres underwater, where lack of enemies and a slow metabolism have allowed them to survive pretty much unchanged.

The backboneed killers flourished, growing in some cases to huge sizes, ten metres and more in length.

With increased oxygen came the first land-life: plants at first, algae, then reeds, then bushes and trees. 345 million years ago, tall, scaly plants covered land surfaces in the first forests. They were the habitat of insects that evolved from spineless sea-life.

As periods of drought dried up seas and lakes, some fish developed the ability to gulp air above the water. Lobe-finned fish evolved

the skill of walking from pool to pool. They eventually became the first amphibians, equally at home in water or on land.

The age of plants lasted 75 million years, laying down the fossil-beds that are today's coalfields. Reptiles, evolving from amphibians, stayed permanently on land. Flying insects developed, including giant dragon-flies, and the cockroaches that have hardly changed in the 300 million years till today.

The first mammals

Closer to our own era, the speed of the multiplication of life forms increased, as the huge pool of genetic information increased with each cell division. The dinosaurs ruled for over 200 million years. In that time, birds emerged and so did warm-blooded mammals – the next inheritors of the Earth.

Then as the dinosaurs vanished perhaps as the climate became too cold for them. Dust from a meteorite bombardment may have shielded the Earth from the sun's rays.

From the sudden extinction of the dinosaurs 65 million years ago, the great diversity of mammal life – from tiny shrews to huge elephant-like mastodons – colonized the planet. Each species was subject to its environment and the pressures of finding food, escaping predators, and successfully multiplying.

Some remain almost unchanged after millions of years, others fell

victims to the relentless logic of 'adapt or die'. It has been calculated that 99.999 per cent of all the life forms that have ever existed are now extinct. Yet today, Man shares the planet with up to ten million other species.

SUPER SURVIVOR



Oxford Scientific Films

One of the world's greatest success stories, cockroaches have existed since 320 million years ago. There are 3,500 known species, ranging from a minute cockroach that rides queen ants, to the ten centimetres long *Blaberus giganteus* of South America. Some cockroaches can live for three months without food and a month without water, others can survive being frozen for two days. They are more resistant to nuclear radiation than humans, and so would be among the survivors of a nuclear war.

Just amazing!

LITTLE AND LARGE

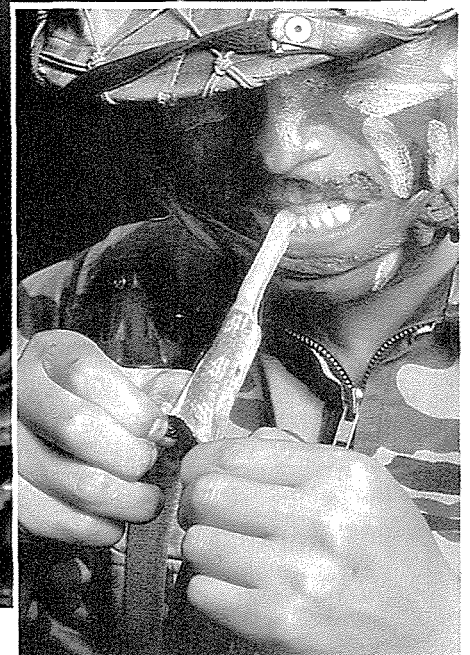
TO GROW BIG AND STRONG, IT HELPS IF YOU EAT YOUR BROTHER OR SISTER. IT SEEMS. EXPERIMENTS SHOW THAT CANNIBALISTIC TADPOLES THAT PREY ON OTHERS GROW INTO MUCH LARGER FROGS THAN THEIR BROTHERS AND SISTERS.



Paul Raymonde



TRAINED TO SURVIVE



Aerospace Publishing

Photo Press International

- Q HUNTING FOR FOOD
- Q SOURCES OF WATER
- Q ADRIFT AT SEA

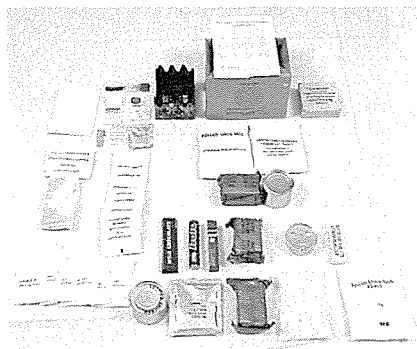
IN PRIMITIVE TIMES, EVERY day was a battle for survival as people had to find their own water, food and shelter. Nowadays, we can buy everything we need and the skills necessary for survival are largely redundant.

The only group of people who are still trained to survive in the wild are soldiers — and they are usually equipped with ration packs for most eventualities. The pack is designed for one or two men and provides a limited balanced diet for combat conditions. The General Service single-man pack weighs 2kg and is rich in proteins and carbohydrates

for stamina and energy. As well as main meals, there is also a variety of chocolate and sweets to be snacked on outside mealtimes, when on the move or when they are resting up.

Squeamishness soon disappears when hunger sets in — a snake makes a nutritious meal, but needs to be skinned before eating.

BASIC SURVIVAL RATIIONS

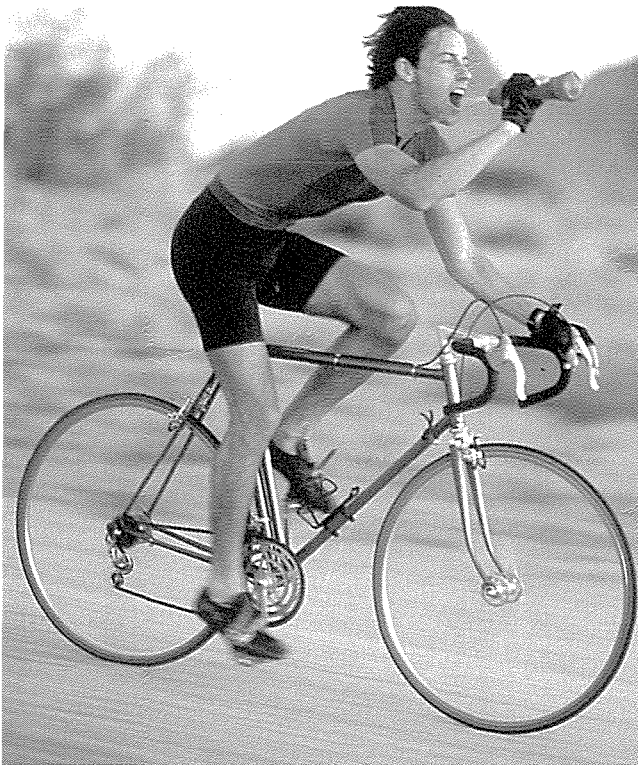


Aerospace Publishing

Army issue survival packs include protein in the form of tins of bacon-grill or bacon burgers, various meat spreads and main meal items such as chicken curry, steak and kidney pudding and minced steak. Carbohydrates include instant porridge, pre-cooked rice and 'heavy' biscuits. Spaghetti and beans provide extra energy. The packs also contain a wide variety of powdered drinks and a selection of chocolate and sweets for use as snacks. A small solid fuel stove is included.

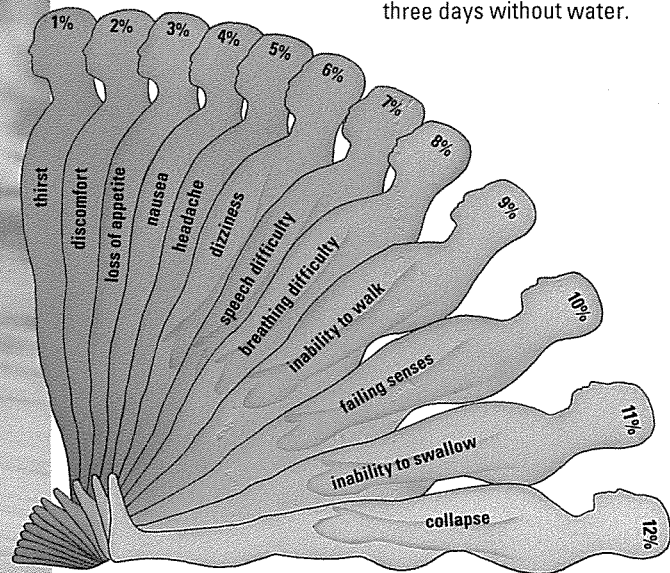


EXERCISE AND THE EFFECTS OF DEHYDRATION



Prolonged, strenuous exercise, such as cycling, can cause dehydration. If this occurs, the victim suffers worsening symptoms with

every one per cent body weight loss, until he or she finally lapses into unconsciousness. Water is essential for survival – a person can survive for three weeks without food, but for only three days without water.



Mark Franklin

Image Bank

The rations in the pack provide plenty of fuel for a period of combat activity, but are severely lacking in fresh produce and can induce constipation after a few days.

The pack comes complete with a small solid fuel stove to heat up the food and to make hot drinks which are essential in cold or damp weather. Powdered coffee, hot chocolate drink, orange, milk and tea bags, plus a meat stock cube and an instant soup provide the incentive to take plenty of liquids: up to one gallon per man daily.

Water loss

Out in the open, carrying heavy loads, travelling fast and far, often over difficult terrain, the soldier on combat duty is very vulnerable to dehydration if he neglects to keep his liquid intake up. Around 60 per cent of the average body weight comprises water and an individual can afford to lose, temporarily, up to ten per cent of this – about six per cent of their total body weight – but any loss must be made up, for the effects of dehydration can be very debilitating.

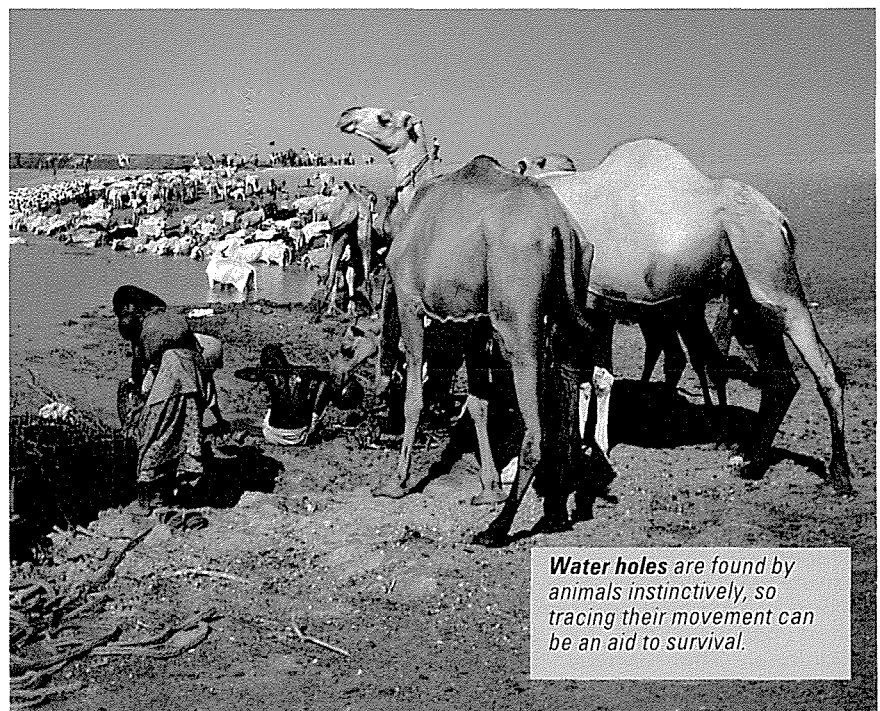
Losing up to two percent of body weight leads to discomfort, with a sticky mouth and tongue, and maybe dry lips. At three percent appetite disappears and at four percent the victim begins to feel intermittent waves of nausea. By this time the dehydrating soldier is in serious need of a drink. Headache and dizziness may accompany further weight loss and by the time seven percent weight loss has occurred, he will experience difficul-

ty in talking. Non-commissioned officers (NCOs) accompanying soldiers under training shoot questions at the soldiers when they start showing signs of dehydration, listening out for incoherence, slurred words and other speech problems.

From here on, the dehydration is beginning to severely disable the victim. With eight percent body weight lost, a person begins to have breathing difficulties; at nine percent down, his legs start to give out and he may walk like a drunk, with

rubbery legs and little sense of direction. Sometimes soldiers on route marches will stride erratically 'straight into a hedge or ditch at the side of the road. With ten percent weight loss, eyesight and hearing become impaired. At 11 percent loss the sufferer is in great distress and unable to swallow, as his tongue and throat swell up. At 12 percent weight loss, he collapses.

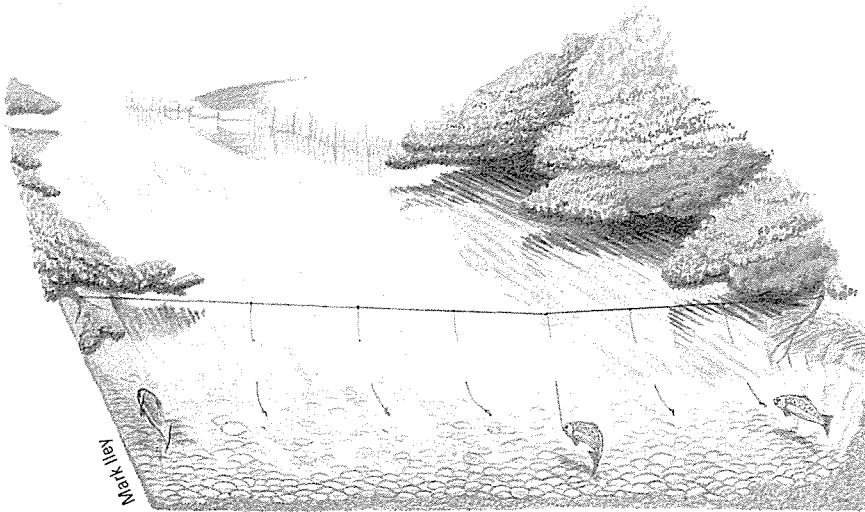
Soldiers in training are pulled out of an exercise and restored with rest and liquids long before this stage is reached. People in real



Water holes are found by animals instinctively, so tracing their movement can be an aid to survival.

Hutchison Library





A static fishing line can be better left unattended. To set up, stretch a piece of cord between two stakes above the surface of the water. Attach several shorter lines to this, each equipped with a baited hook. This is a useful technique when fighting for survival, but under normal circumstance fixed lines are illegal in the UK.

Spearing fish is another useful fishing technique – a tree branch carved to a sharp point makes an ideal weapon.

emergencies may not be so lucky. Long before collapse, they are incapable of actually seeking out water, so even the early stages of dehydration represent a warning that would be suicidal to ignore.

Survival in the wild

Once the ration packs have given out, the soldier, or indeed anyone lost or caught out in the wild, has to become a hunter gatherer like his ancestors many thousands of years ago. In temperate climates, the game can consist of rabbits and hares, a large variety of birds (and their eggs), mice, rats, squirrels, snakes and fish. If a soldier is prepared, he may be carrying wire snares, fishing hooks and line, or even a catapult. All of these can be improvised if necessary. If he is in a particular region for any length of time he can carefully survey it for regular animal tracks, note where birds perch or nest for the night and spy out where big fish lie against the stream bank, or in the shadow of a rock.

Simple spears are easy to make using a knife. If the end of the spear is split and the gap held open with a small wedge, then both sides can be sharpened and carved to have rough barbs which will provide an

Without food rations, climbers could not survive. Melted snow would provide water, but finding food would be almost impossible on mountain sides.



Paul Henley/Tropix

Slugs and snails may not appear to be appetizing, but in Australia witchety grubs are eaten by Aborigines as a matter of course.

efficient fishing spear. During the day, the hunter must stand in the water with the spear poised and thrust below where the fish seems to be – this is difficult as refraction of light through water distorts the image. At night a blazing torch – birch bark makes a good, long burning torch – can be used to attract fish for spearing.

Animal snares must be set up where animals regularly pass. Tracks, worn grass and wisps of fur give their runs away. A simple loop-snare may do the trick, but it is better if attached to a spring in the form of a bent-over, resilient



Hutchison Library

branch, held lightly in place by a notch in a firm stake. The impetus of the animal hitting the snare frees the bent branch, which springs straight, tightening the noose.

Cooking the catch

Caught game, animal, fish or bird, needs to be gutted. The guts can be retained as bait, although the liver and heart can be eaten. Once hunger has taken over, flesh can be eaten raw. Alternatively, small game, fish and birds can be cooked over a fire on an improvised spit. It is better to do this over glowing embers rather than over flames.



Chris Bonington/Bruce Coleman Limited



Plant food can be found from the Arctic to the equator, with the exception of some arid desert regions. With plants, especially mushrooms and other fungi, recognition is essential as many are inedible, poisonous or deadly. If in doubt, do not eat. In the Arctic mosses and lichens are nutritious, and in coastal regions some seaweeds are an excellent form of food.

Water sources

Anyone who has to survive in the wilderness soon learns to find water in low-lying ground, in the hollows of trees and in seepages from cliff bases. Also watching animals or listening for signs such as croak-

Solar stills are often part of life raft equipment. These work by condensing sea water and collecting the condensation.

ing frogs, can pinpoint potential water sources. Dew can be collected by sponging it up from long grass and shrubs with an item of absorbent clothing and carefully wringing it out into a container.

Desert survival requires both shelter and a source of water. Cactuses and roots are possible sources, but a solar still is an efficient way to distil water out of the ground. A hole of one metre across and 50cm deep can be dug out and a container placed in the bottom. If the hole is covered with a piece of plastic sheeting, large enough to form a cone-shape when weighted in the centre with a pebble, and secured with rocks around the edges, the heat of the day will produce water vapour from the trapped air and the earth beneath it. This will condense on the underside of the plastic and run down to drip

MAKE AN EARTH OVEN

Larger items of food can be cooked in an earth oven. Dig a hole 50 cm deep and 25 cm across. Heat several small boulders in a fire for at least one hour and drop them into the hole. Drive a stake into the centre of the hole and surround it with loose earth, placed on top of the boulders. Follow with a layer of green vegetation, such as grasses. A skinned animal or large joint from a deer or a pig can now be placed on top, followed by another layer of vegetation, then another layer of earth. The hole should be almost filled. The stake should then be pulled out and the resulting hole filled with about one litre of water. The whole oven should immediately be capped with a large rock and any gaps sealed with earth. This oven will act like a pressure cooker and the meat will be fully cooked in a couple of hours.

watery fluid can be found along the spinal bone of some large fish and the eyeballs are also a good source of drinkable liquid. Some sea survivors have obtained nutriment from seabirds, grabbed when they land on the boat. Another food source is seaweed, which can be snagged with a home-made grappling iron dragged behind the vessel.

Squeamishness soon disappears with hunger and thirst. British Marines and Paratroopers are taught the protein value of the worm omelette early in training. Earth-worms, snails, grubs and slugs are all good sources of protein. They can be dried out in the sun and added to stews, or mixed with scrambled birds' eggs.

FOOD FROM THE SEA

Seaweeds are a good source of protein and minerals – in Wales they are used to make laver bread. Seaweeds are not poisonous, but some types contain a type of acid which can irritate the digestive tract. To check, crush the weed well between your fingers, then leave it for five minutes – if it does contain the acid it will give off an unpleasant smell.

into the container. A still can produce over half a litre every 24 hours. If enough plastic is available, a series of stills is the best method of producing a vital amount of water.

Survival at sea

Some people have managed to survive for months at sea in open boats or life-rafts, living on whatever water and food they could get from their immediate environment. Some have lived on the turtles and fish attracted to the shade of their vessel, catching the turtles with a simple rope noose, and baiting homemade hooks with lures of rag (or pieces of turtle) to catch fish. With minimum exertion, and some form of shading canopy, survival on less than one litre of water a day is possible.

A day without water closes the kidneys down to a certain extent and supplies can then be rationed to about 400ml per day for the next three days. A strict regime of up to a quarter of a litre per day, if available, can then be followed. Apart from rain water caught in sails or cloths, some life-rafts have solar stills. Fish can also be a source of water –



Avon Inflatables



Lythgoe/Planet Earth Pictures



- SCALING HEIGHTS
- PLUMBING DEPTHS
- NATURAL HAZARDS

MAN AGAINST NATURE

Dave Pace/DMM International

THE EXPOSURE TO DANGER, the elements or hostile terrain, the confrontation with nature at its most savage and the sense of achievement after completing a difficult climb or a journey into the bowels of the earth give many of the more dangerous sports their main attraction.

Strenuous exertion at high altitudes brings about an increase in a climber's breathing rate and blood flow.

Underground caverns are excavated by millions of years of water seepage.

What goes up must come down, and a climber encounters just as many hazards when he or she makes the return journey.

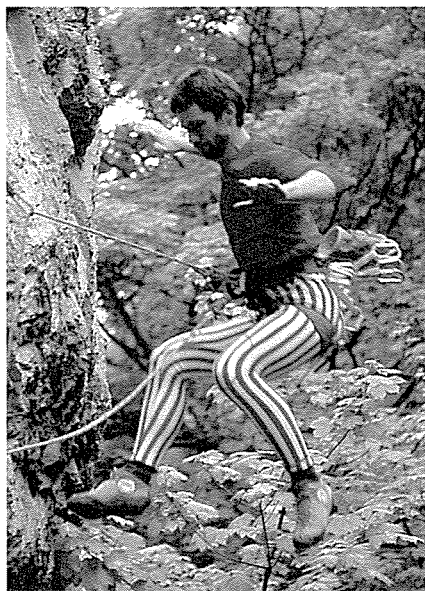
Despite the dangers inherent in sports such as mountaineering and potholing and the fact that most of the highest mountains or deepest potholes have already been conquered, the urge to compete against nature remains as vital as ever.

Mountaineering

Climbing mountains is a supreme test of physical and emotional fitness. For not only do moun-

taineers need the strength to literally pull themselves up mountains and the nerve to cling to sheer rock faces supported only by a small steel piton, they also need to cope with the greater problems of surviving high altitudes without using oxygen cylinders.

As altitude increases, air pressure decreases and there is less oxygen to breathe. This lack of oxygen causes changes in processes within

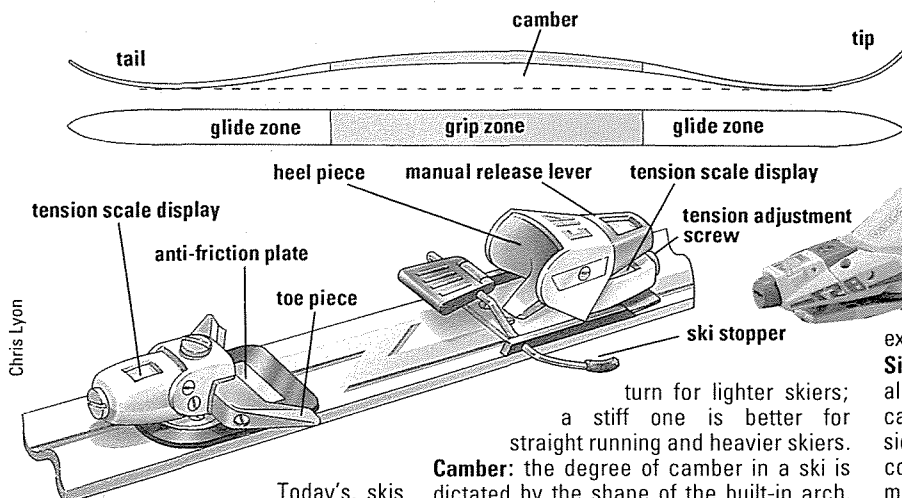


Ian Smith/Troll



Allsport/Vandystadt





Today's, skis are fine precision tools specifically designed to meet the demands of the different types of competition. **Flexibility:** a range of flexibility can be achieved with modern composite materials such as fibreglass. A pliable ski is easier to

Camber: the degree of camber in a ski is dictated by the shape of the built-in arch. This arch allows the skier's weight to be distributed along the whole length of the ski. The camber also provides a springboard effect which helps to lift the skis for turning. Too much camber makes turning hard work; too little leads to the

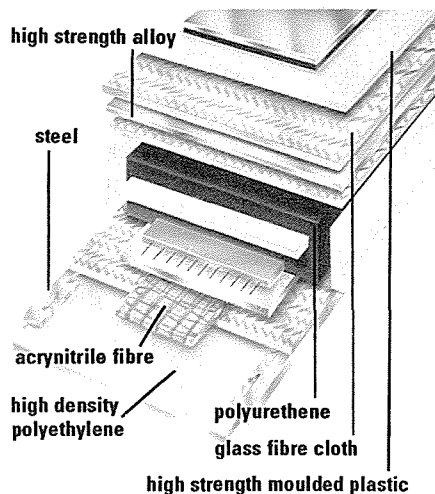
extremities not getting a grip and sticking.

Sidecut: most skis are waisted – narrow along the length. The degree of waisting is called sidecut. When the ski is laid on its side by knee movement, the tip of a ski with considerable sidecut will bite and turn more than that of a non-waisted ski.

Bindings: ski bindings are designed to clamp the boot firmly on to the ski, but to release the skis if the skier falls.

Boot: all boots have a rigid plastic outer shell that is angled forward, plus a hinge at the ankle to allow forward movement.

Ski components are bonded together in a mould under high pressure and heat.



the body which can lead to major medical problems if the body does not adapt to them and the person remains at high altitude for too long.

As there is little stored oxygen in the body, man is dependent on an elaborate and highly integrated series of mechanisms to transfer oxygen from the air to individual cells. Each link in the oxygen transport chain undergoes some modification on exposure to altitude, beginning almost immediately.

Breathing increases, carbon dioxide is lost and the pressure of oxygen increases in the alveoli – the tiny pockets of lung tissue which transfer oxygen from the air to the blood. This increased pressure enables oxygen to pass into the capillary network within the lungs more efficiently.

The diffusing capacity of the lungs – the ability to disperse oxygen into the blood – is one of the factors that sets the limit for exercise at high altitudes. On exertion, oxygen pressure in the blood falls dramatically despite the pressure in the alveoli remaining high. In well adapted mountaineers, the diffusing capacity can be almost three times higher than normal.

Skiing

In some parts of the world, the local population view skiing as a natural way of moving across country in the winter time. Tourists to these areas see it as a pleasant form of exercise, while embracing the pleasures of après-ski nightlife with greater enthusiasm. But for the true enthusiast, skiing is a test of skill and judgement and an opportunity to conquer the slopes at ever increasing speeds.

Alpine ski racing comprises downhill and slalom events. The average downhill course has a vertical descent of between 800 and 1,000 metres and a length ranging from 2.5 to 5 km, according to the nature of the terrain available. A winner's average speed is usually in excess of 80 km/h.

Slalom courses are considerably shorter than downhill ones and have a series of pairs of poles with flags, known as gates. These are carefully positioned at different angles to test the judgement, fluency of movement, power of control and skill in turning of the skier.

Mountain hazard

People who live in the mountains understand the nature of this environment, but visiting skiers often

believe they can ski almost anywhere and take liberties with nature. When they do this, they lay themselves open to suffering the devastating effects of the destructive powers of avalanches.

An avalanche is triggered when snow on a slope is overloaded with piles of new snow, or the snow changes internally so its bond with the ground beneath is weakened. Any additional weight can send the mountain snow crashing down with a mighty roar.

When there is a temperature difference between land and air, say at the beginning of winter when the soil temperature is perhaps 0°C, then a natural process called constructive metamorphosis will occur.

MONOSKIING

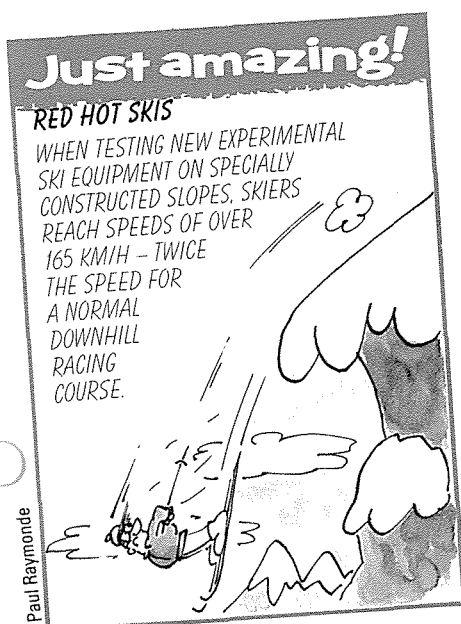
For the expert skier who has mastered the slopes on two skis, the next step is to attempt them on one. The monoski has a sandwich construction and is made of fibreglass with a polyurethane core. It can be used on piste and off-piste and handles varying snow conditions well.



Airwave Gliders

Cup-shaped crystals, called depth hoar, develop and produce a very weak structure that can avalanche. The snow crystals may be more or less frozen together, but if the temperature rises above 0°C then the structure is weakened further.

New snow, which accumulates on the steepest slopes, can be blown by wind to form cornices which are huge overhanging masses of snow, around the top of mountains. On steep slopes the snow soon becomes unstable. Sunshine on fresh snow speeds up the process and without warning snow slides soon set in.



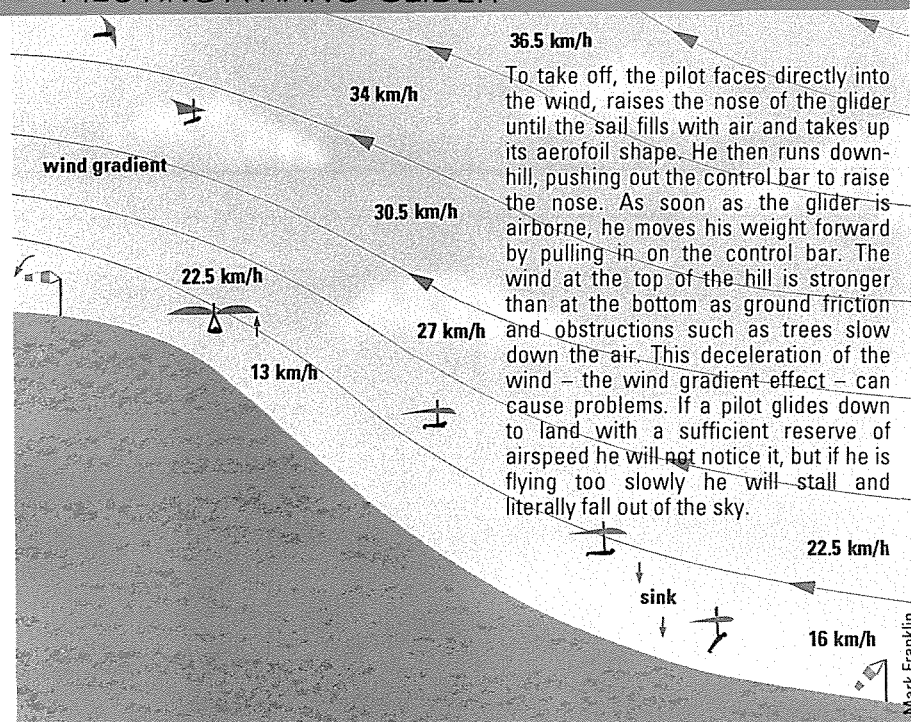
Paul Raymond

Just amazing!

RED HOT SKIS

WHEN TESTING NEW EXPERIMENTAL SKI EQUIPMENT ON SPECIALLY CONSTRUCTED SLOPES, SKIERS REACH SPEEDS OF OVER 165 KM/H – TWICE THE SPEED FOR A NORMAL DOWNHILL RACING COURSE.

PILOTING A HANG-GLIDER



The glider soars in the air deflected upwards by hills and ridges – these rising currents can be detected by clouds.

Just as some adventurers have a desire to conquer heights, others prefer to plumb the depths – underground tunnels and caverns full of stalactites and stalagmites.

Potholing

Potholes – caves which start with vertical shafts – exist in limestone regions. In many ways, venturing underground is more dangerous than climbing. The falls can be as steep and there is the added danger of underground water.

The evolution of equipment and techniques for potholing has progressed rapidly over the last decade. Most professionals now use a fixed rope down steep climbs and along passages, and each member of the group clips himself to the rope.

The other essential piece of equipment is a harness that can be clipped on to the rope. The simplest version is a load-bearing belt, but these are made safer if used with leg loops.

Metal clamps – jammers – are used for climbing up ropes. These slide freely if pulled up, but fasten firmly on to the rope if pulled downwards. To slide down ropes, potholers use a descender. The rope is threaded from the anchor point around the bottom bobbin on the descender, then around the top bobbin before being clipped into a steel karabiner – a coupling link with a safety closure.

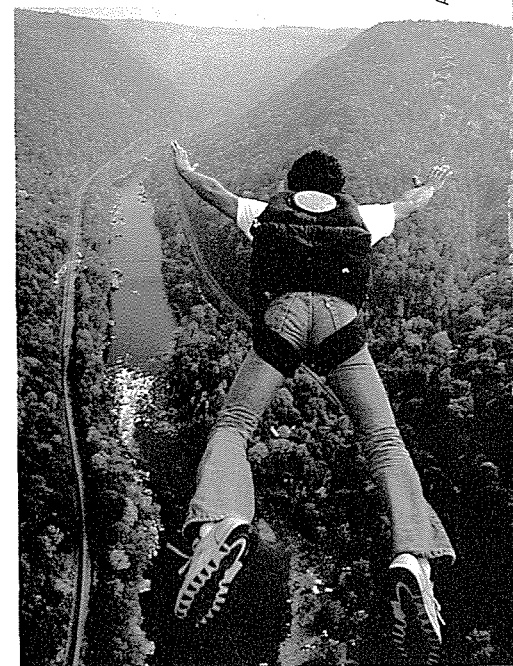
Well-maintained equipment can diminish the risks involved in the climbing aspect of potholing, but common sense and the correct

waterproof clothing are needed to reduce the other inherent danger in this sport – water.

The water in cave passages can come nearly to the top of the passage (a duck) or even fill the passage completely (a sump). In the case of the former, often the only way to cross the passage is to hold your head to one side to keep your nostrils above water, lying on your back if the passage is shallow.

When a sump is encountered it can be free-dived using a lungful of air. But experienced potholers will never attempt this unless they are familiar with the passage.

Allsport/Vandystadt



When free-falling, a parachutist falls several hundred feet before releasing the parachute.



Robert Harding Picture Library



Buzkashi, popular in Afghanistan, is a form of polo, involving up to 300 riders and a decapitated calf.

Tossing the caber – a roughly trimmed tree trunk – is a sport restricted to Scottish Highland games.

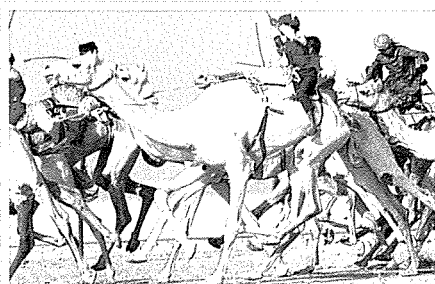


Mongolian wrestling appears similar in style to Graeco-Roman – a mix of ancient Greek and Roman – and is now accepted by the International Federation of Wrestling as a recognized sport.



ZEFA

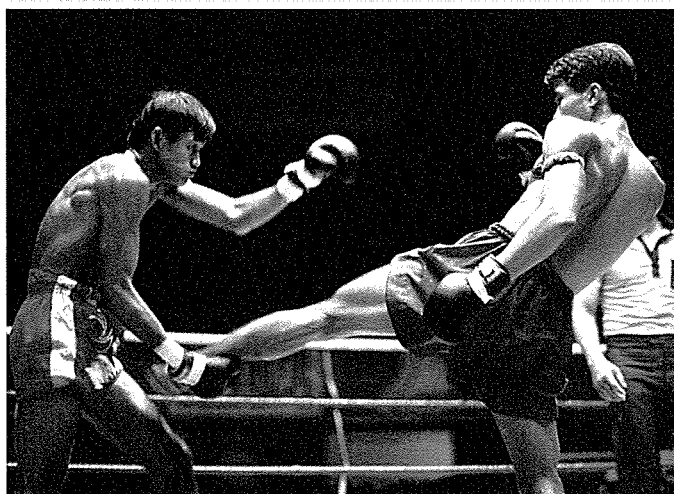
Camel racing, a sport long popular in Saudi Arabia, is now gaining popularity in Australia. A good racing camel can cost over £50,000.



Allsport/David Cannon

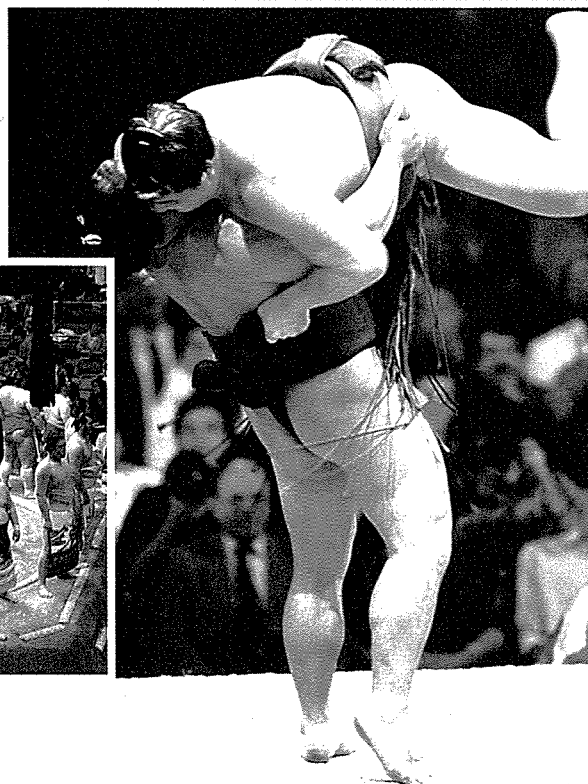
Boxing in Thailand is a much faster event than Western-style boxing. Fighters are allowed to use their feet as well as their hands and a skilled boxer can knock his opponent off balance with a well aimed kick.

Robert Harding Picture Library



Allsport/Simon Bruty

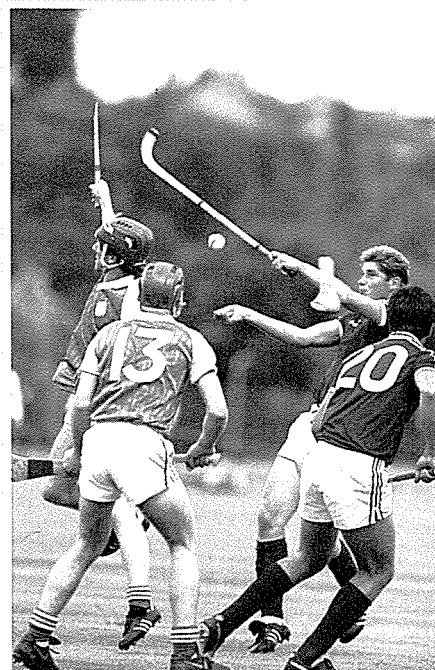
Sumo, the traditional spectacle of Japanese wrestling, is fought out with tremendous ceremony by men all over 150 kg. Ozeki, first class wrestlers, hold a ritual entrance parade (below).



Allsport/Vandystadt Cephas Picture Library/Nigel Blythe



Allsport/Russell Cheyne



Shinty, a Gaelic field game which originated in Scotland, is played by two teams of 12 men. A caman, an instrument similar to a hockey stick, is used to hit the ball during the matches.

■ RIDING THE WAVES

■ ANGLE OF ATTACK

■ SLALOM CANOES

Conquering the Waves

NEXT TO FIRE, WATER IS ONE of the greatest dangers to man if not kept under control. The power of the sea can be an irresistible challenge to some and can lead to a burning desire to utilize or harness that power.

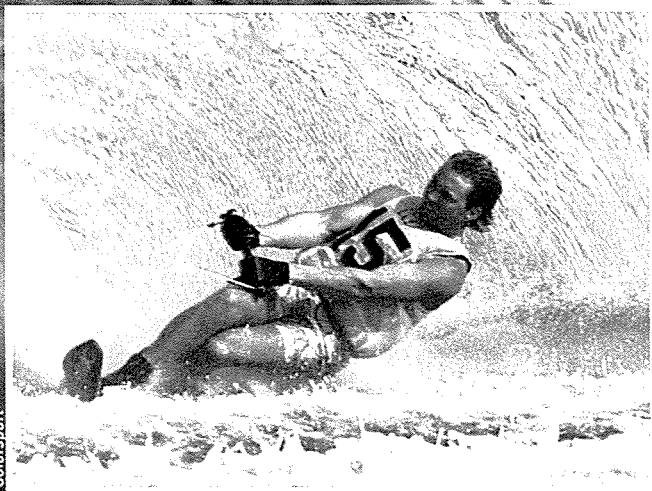
Swimming is one of the first skills many children learn and once they have lost any initial fear of water, it can lead to a real love of all types of water sports.

Surfing depends on waves, and waves are caused by the action of wind on water. Typically, during the day, winds blow on-shore because dry land heats up quicker than the sea. The air above the hot land rises and, by convection, draws in the wind that brings the ocean waves rolling and roaring on to the beaches. Waves form on rocky coasts as well as on sandy ones, but the best waves for surfing develop on sandy

Allsport/Cavataio

Slalom competitors are pulled through a course containing six diagonally placed buoys. This calls for skill in timing, turning and crossing the wake of the towing boat.

Expert surfers can stand towards the front of the board, but beginners find it easier to balance if they keep in the middle or near the back.



Coloursport



SURFING WAVES

120°

Janos Marffy

As waves grow, their crests get steeper until they reach the angle of 120°, at which point they become unstable and break, producing whitecaps. The plunging breaker – 'dumper' as it is known in surf slang – occurs where there is an abrupt rise of the ocean bottom to shore.

shores where the water gradually becomes shallower.

Training for surfing usually begins by body surfing. The surfer swims out from the shore and awaits a high wave. As one wave starts in towards the shore, the swimmer does a scissors kick and swims a few strokes at the crest. Then, with arms by his sides, head down and back arched, he is swept along towards the beach. The feel of the surf and the sense of balance is all part of becoming a surfer.

For a surfboard ride, the surfer paddles the surfboard out to the point where waves build up. As a big

wave develops, he paddles his board ahead of it until it starts to be carried by the wave. He then stands up and guides the board across the face of the wave by shifting the weight of his body. Expert surfers can move to the front of the board, but beginners find it easier to stand at the middle or rear to keep it from turning over.

Many different styles of surfboard are used, but most are made of a tough plastic or fibreglass and are around three metres long, 75 cm wide, 10 cm deep and weigh about 5 kg. The buoyancy of the surfboard is such that surfer and board float and it is the skills of coordination and balance that lead to the long, impressive, exhilarating ride to the shore.

Windsurfing

If a couple of downward-pointing fins are attached to the board and a triangular sail attached to its top,

SURF TALK

Goofy-foot: a rider who surfs with his right foot forward

Hang five or ten: placing five or ten toes over the nose of the board

Hot-dogging: performing or showing a great deal of ability on a moving surfboard

Pipeline: space under a curling wave

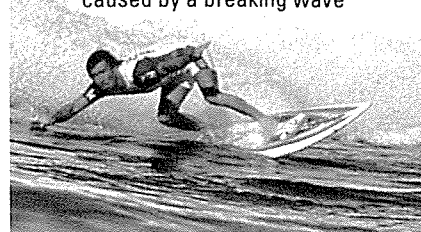
Re-entry: turning up a wave then back on to the soup

Soup: foam, the result of a breaking wave

Stalling: depressing tail to slow down or stop the board

Take-off: when surfer begins to ride a wave

Wipe-out: Loss of a board, usually caused by a breaking wave



Alisport/Vince Cavataio

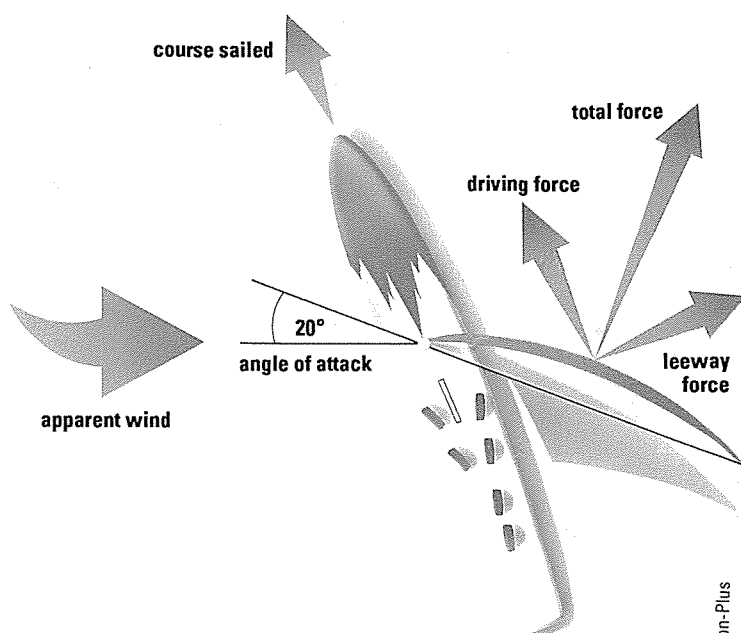
the result is the windsurfer capable, in some hands, of wave jumping and looping the loop.

Windsurf boards now take many forms and are chosen depending on the skill of the surfer, the weather conditions they are to operate in and the performance expected.

The sail acts best when it is

Looping the loop – an expert windsurfer in Hawaii, where the waves break under almost continuous 25 km/h winds.

USING WIND POWER



Action-Plus





Colorsport

Canoeing is a collective name for a variety of sports, from white water raft racing, to single-man kayaking. In a single-man canoe, competitors roll to right themselves when the vessel overturns. In two-man canoes or inflatable racing rafts which hold several individuals, it is a case of 'abandon ship' (but not paddles!) if the vessel overturns in turbulent waters.

performing like an aerofoil and the wind is striking the mast at right-angles to the intended direction of travel. This is called a 'reach' and the maximum amount of reduced pressure is developed on the convex side of the sail – the windsurfer is literally sucked along. The importance of the daggerboard, or keel, lies in preventing the board from sliding sideways through the water and in converting the sideways push of the wind into forward motion.

Superficially, water skiing and surfing might look as though they relied on the same scientific princi-

ples. However, this is not so. The combination of surfer plus board is bouyant; that is, together they float – even when not moving. This is because the board displaces a sufficient mass of water to provide enough upthrust to stop the surfer from sinking. Water skis, by contrast, have little buoyancy. They are just flat pieces of wood or plastic, curved upwards at the leading edge and carrying footholds.

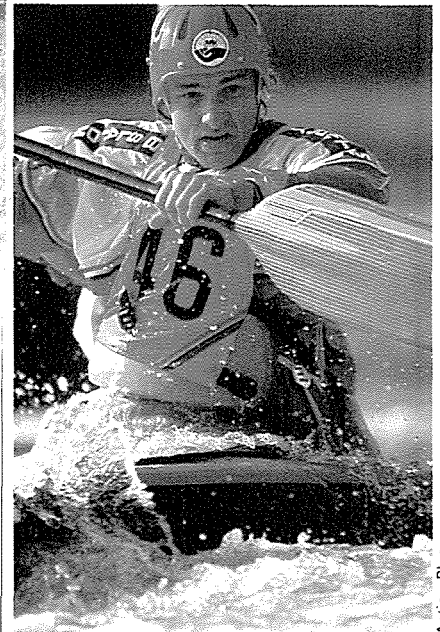
Skiing on water

In order for the water skier to skim on the surface of the water, upthrust has to be gained from somewhere – and it comes from the pushing force of water moving at speed beneath the ski. The skill of the water skier lies in adjusting the angle of attack of the skis and the position of the body's centre of gravity so that, at all speeds, there is a dynamic balance between the pulling force provided via the rope to the skier's hands, the upthrust from the skis and the force of gravity which is trying to make the skier take a dive.

To 'get up', a speed of around 15 to 18 knots is usually needed. For this to be achieved, a boat with a 25 horsepower outboard engine or a 50 horsepower inboard engine is needed. The tow rope is about 25 metres long.

Canoeing

To fight – and to conquer – the ferocity of turbulent water armed only with a light plastic hull and a pair of paddles is one of the great sporting challenges. It is hard enough to navigate a canoe over a weir or down rapids. More difficult still are competitions, which involve the precise positioning of the canoe in waters that are crashing downwards at crazy angles at a rate of thousands of tonnes per minute

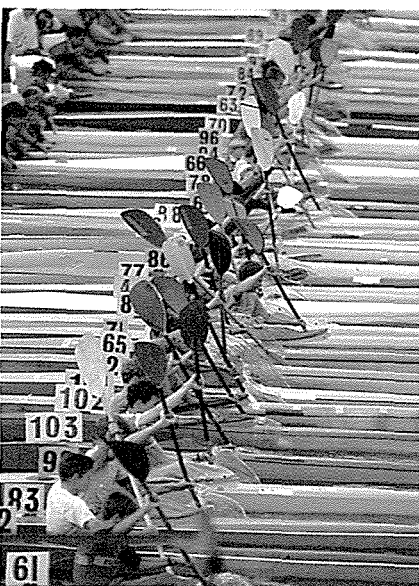


Action-Plus

between rocks and boulders. The canoeist must pass through gates formed by poles suspended above the river and this requires courage, timing, strength and fitness.

The canoe used for this type of competition is the Slalom type which combines lightness, manoeuvrability and toughness. Slalom canoes are made of plastics such as Kevlar and Royalex. Fibreglass was once the preferred material, but it was too susceptible to

Ideal racing conditions are on a windless, still-water man-made course that is sufficiently deep to eliminate bottom drag – a disturbance of the water under the surface which reflects off the bottom of the boat, slowing it.



Allsport/Russell Cheyne

Just amazing!

BEEN DONE BEFORE

USING OUTSIZE SHOES AS FLOATS, FRITZ WEBER WALKED OVER 300 KM ON THE SURFACE OF THE RIVER MAIN BETWEEN BEYREUTH AND MAINZ.



Paul Raymond



cracking and holing (particularly at low temperatures) when striking rocks. The new plastics are more resilient.

Modern sports canoes have regions, fore and aft, filled with solid plastic foam. Water cannot penetrate these areas, so the canoe cannot sink. Although it is almost impossible to sink a canoe, its shape and distribution of weight make it fairly easy to turn over. With the canoeist underwater and all that buoyancy then above him it can be difficult to right it. However it is vital, if the canoeist is not to drown, that this be done as quickly and efficiently as possible. Rolling is, therefore, the first exercise a canoeist will practise, often in a swimming pool, learning the various ways of using the body's weight, together with the paddles underwater, to revolve the canoe back upright.

Rowing

Rowing must be a unique sport in that all but a minute minority of its competitors spend their time travell-

ing facing backwards. The minute minority are tiny in number – and in size, for these are the coxes, and the first and foremost attribute of a cox is that he must be light. The less the dead-weight in a racing boat, the easier it is for the rowers. The small cox does not even have to have a large voice these days because audio links between cox and oarsmen make a normal speaking voice level perfectly adequate.

Lightness, yet great strength of hull, is achieved by extensive use of carbon fibre, both in the boat itself and in the blades.

The boat is powered forwards by a system of levers – two, four or eight. One end of each lever (blade, or oar) is in the water, the other is in the hands of an oarsman. Between the two is the rowlock, or the fulcrum of the lever. The forward, driving force is delivered to the boat



Racing to the finish, the Oxford and Cambridge boat race (left) is sedate compared to the lifeguard race in turbulent waters, where the oarsmen row without guidance.

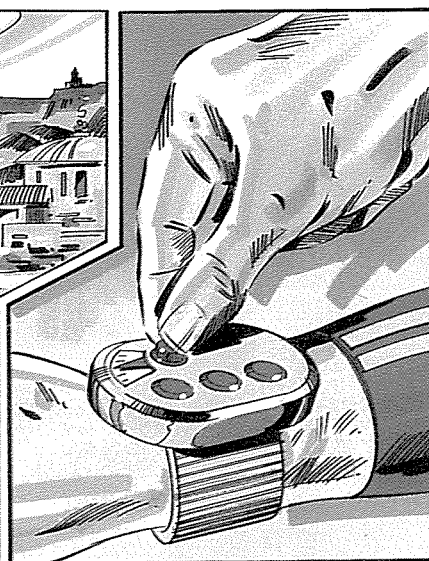
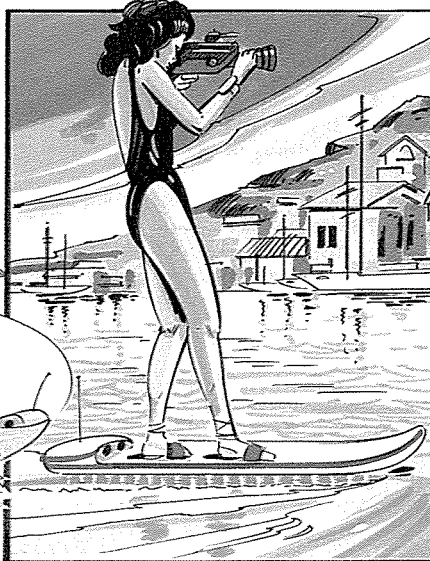
through this fulcrum, but the force has its origin in the muscles of the crew, who are seated on running seats that allow maximum use to be made of not only the muscles of back and arm but of the legs as well. When each crew member is equipped with two short light oars instead of one long one, the sport is called sculling.



Alisport/Dan Smith

INTO THE FUTURE

ROCKET-PROPELLED SKI BOARD



▲ Rocket-propelled ski boards will enable sportsmen to enjoy the pleasures of high-speed water skiing without the need for a boat to tow them.

▲ In hover mode, part of the engine's thrust will be directed downwards through holes in the bottom of the board, thus supporting it on a cushion of gas.

▲ An electronic remote-control unit strapped to the wrist will give the sportsman complete control over the machine from the standing position.



- ☐ KILLER WINDS
- ☐ LIGHTNING STRIKES
- ☐ BURIED BY SNOW

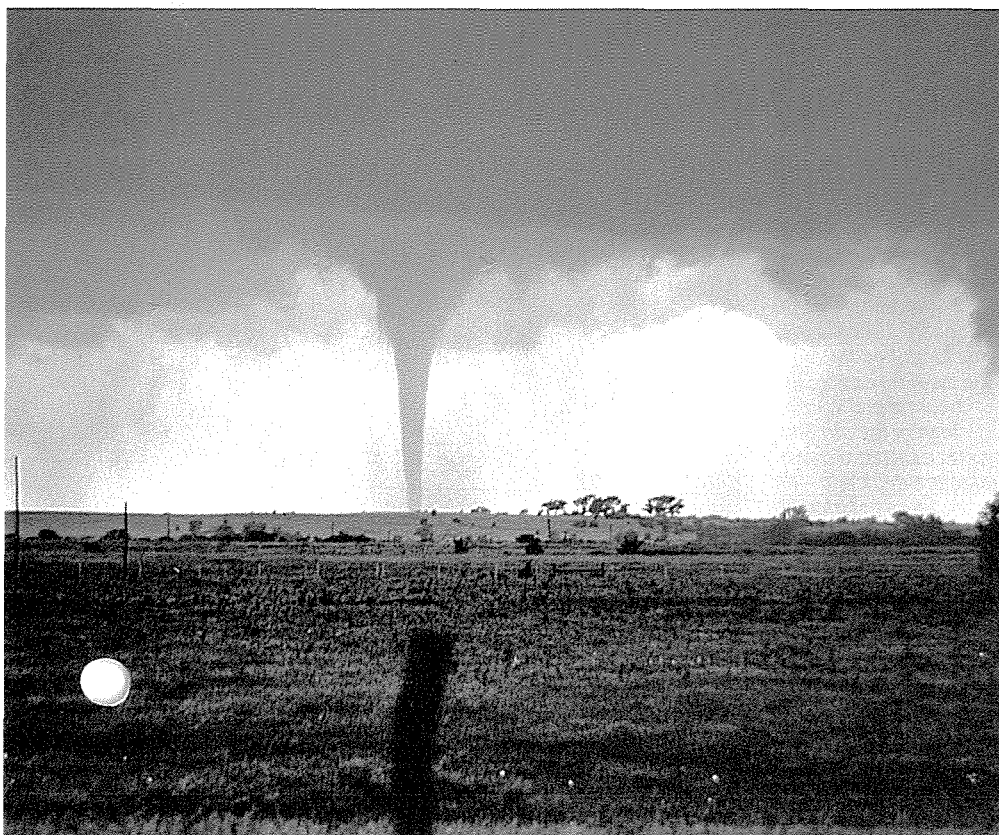
Frank Lane Picture Agency

NATURE'S FORCES

NASA



The eye of the hurricane, an area of calm amidst mayhem, revealed by satellite. Total devastation follows in the hurricane's wake (inset above).



Frank Lane Picture Agency

LIGHT WINDS, RAIN OR SNOW are the least of the weather's tricks. When it feels in the mood, it can blow you off your feet, hit you on the head with a huge hailstone, then finish you off with a massive electrical jolt from a lightning bolt.

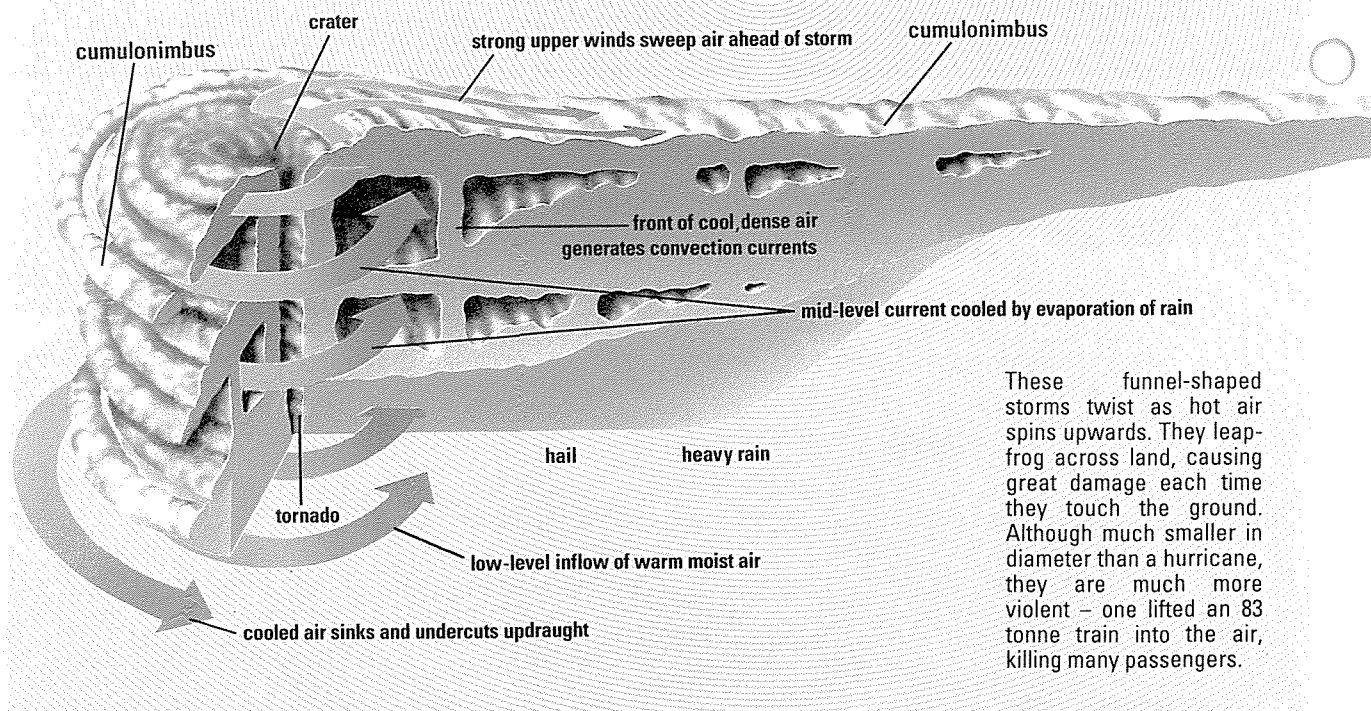
The destructive power of certain types of weather is enormous. For instance, the storms that develop in the tropics can wreak widespread devastation. When the wind speed of tropical storms gets to more than 118 km/h, these tropical cyclones are given names. In the Caribbean they are called hurricanes; in the Far East, typhoons; in India, cyclones; in the Philippines, tropical cyclones; and in northern Australia, willy-willies or cyclones.

This very violent type of tropical cyclone can only develop in a zone about 5–15° each side of the equator, where there is a great deal of warming energy from the Sun and the temperature of the sea

Swirling from the clouds to the ground, tornadoes can travel at speeds of 70 km/h. Although smaller than hurricanes, they wreak just as much havoc.



TORNADOES – THE TERRIBLE TWISTERS



Janos Marffy

These funnel-shaped storms twist as hot air spins upwards. They leap-frog across land, causing great damage each time they touch the ground. Although much smaller in diameter than a hurricane, they are much more violent – one lifted an 83 tonne train into the air, killing many passengers.



John Cleare/Mountain Camera

Blizzards strike without warning, making roads impassable and cutting off communications. Heavy snow, blown by strong winds, can even bury houses and vehicles.

the USA, with some in Australia, South America, Europe and southern Africa. The wind speed in tornadoes is enough to flatten everything in their path. They usually move across land at about 70km/h and travel distances of 16–64km. Their wind speed is so great that it can only be estimated.

A tornado forms in large cumulonimbus (thunderstorm) clouds

Pertti Luoma/Met

water is higher than 27°C. Once the cyclone has moved out of the tropical zone, it either dies out at latitudes 40° away from the equator or dissipates its energy over land, where it cannot be fuelled by rising hot moist air.

Untamed violence

In the Bay of Bengal, in November 1970, a cyclone caused such destruction in Bangladesh that about 250,000 people died. In fact, that part of the world has the dubious record of the most fatal tropical cyclone ever – 300,000 people were drowned in 1737.

In October 1987, south-east England had hurricane-force winds with loss of life and destruction of property. This was not a tropical storm a long way from home, but an exceptionally violent depression – a most unusual event so far from the dangerous air of the equator.

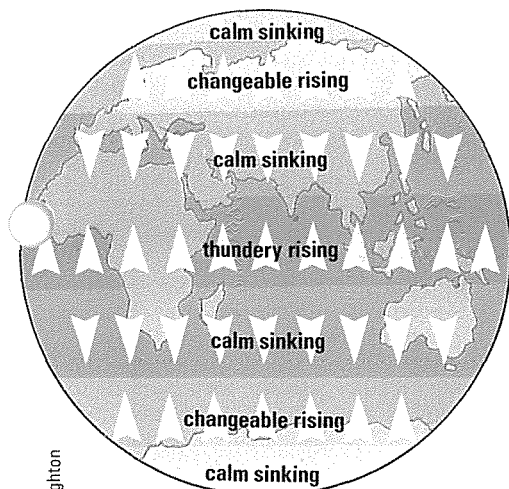
Encased in ice, this Greek ship was a casualty of a storm in the Baltic sea in January 1979. As the ship ploughed through the swirling ocean, its bow spread waves high in the air. The water splattered down on to the deck and – in temperatures of almost minus 20°C – quickly froze.



Tornadoes are much smaller than hurricanes, but despite being on average only a hundred metres wide – compared with the total hurricane system size of 500km – they are much more vicious. Tornadoes only form over land and most happen in

when severe storms are taking place – fast-moving humid winds blowing in opposite directions within these large clouds meet and spiral round each other, sucking in air as they go. As it develops, it looks like a whirling, funnel-shaped





John Houghton

Air pressure zones: warm tropical air rises all the way to the top of the troposphere, then moves off towards the poles. The cold air at the poles sinks and moves down towards the equator. In between there are zones of rising and sinking air. When the air is cold and sinking, the weather is dry and settled. When air is rising, however, the weather is disturbed as the rising air cools, expands and condenses into heavy clouds, often bringing thunderly weather.

Sabine Weiss/SPL



Frank Lane Picture Agency

Dust devils occur in hot desert areas as a result of spirals of warm air rising off the baked earth and sweeping up dust into a column-like shape. They can reach a height of 60 metres and last only a few minutes. Sandstorms (below) can whip sand up as high as 3,000 metres and can strip paint off cars.



THE BEAUFORT SCALE

Storm warnings on the radio use the Beaufort Scale. The force goes from 0

to 12: each has its own description, minimum wind speed and effects.

Force	Strength	Speed (km/h)	Effects
0	Calm	0	Smoke rises vertically
1	Light air	1+	Smoke drifts slowly
2	Light breeze	6+	Leaves rustle
3	Gentle breeze	12+	Twigs move, flags unfurl
4	Moderate breeze	20+	Dust blows around
5	Fresh breeze	30+	Small trees move
6	Strong breeze	40+	Large branches sway
7	Near gale	51+	Trees sway; difficult to walk into wind
8	Gale	62+	Twigs break off trees; walking is hard
9	Strong gale	75+	Roof tiles and branches blow down
10	Storm	88+	Trees uproot; damage to buildings
11	Violent storm	102+	Widespread damage
12	Hurricane	120+	Large scale devastation

superstructure would probably be blown away — or to look where the tornado was going and run away at right angles from its path. This is still the best policy if you are caught out in the open with a tornado bearing down. Modern reinforced concrete buildings are strong enough to withstand the wind, but watch out for flying glass.

Hail and snow

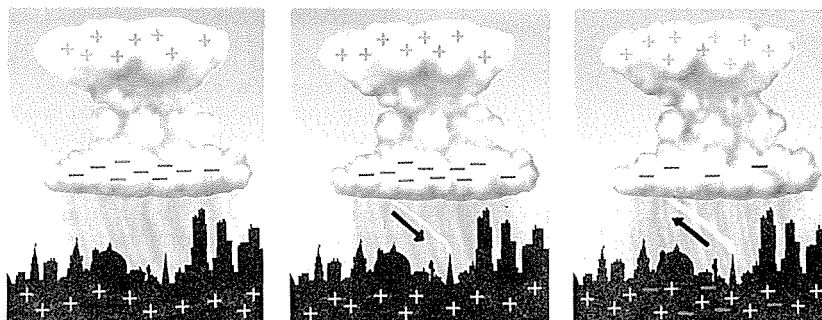
When the air is cold enough, snow falls instead of rain. Most rain starts off its life as snow or ice crystals way up in the tall clouds where the temperature is low. As the crystals come down, they melt and raindrops form. When the air temperature is low enough, the snowflakes

elephant's trunk stretching down from the cloud to the ground. Rain comes before the wind and rain and hail follow it.

There is a strong upward air current in the middle of a tornado, which sucks up things in its path — leading to some bizarre happenings. Any house or building below the tornado 'explodes' because of the intense pressure difference. Trains have been lifted tens of metres up in the air before being dashed to the ground. The most destructive tornado happened in March 1925, in Missouri, USA, when a tornado 274 metres in diameter swept across the land, killing 700 people and laying waste everything in its path.

The only way to survive a tornado in times gone by was to get into a storm cellar under a house — the

THUNDER AND LIGHTNING



Electrical charges build up in the cloud: positive charges at the top, negative ones at the bottom. A leader stroke discharges the negative charge in the

cloud into the positively charged earth. A return stroke then flashes up from the ground, heating the air, which expands with a thunderous bang.

Janos Marffy





J.G. Golden/SPL

— formed by the gradual crystallizing of tiny water droplets on to microscopic ice crystals that increase in size — can fall all the way to the ground when the updraughts in the cloud are no longer able to support them.

Hailstones are another menace from cumulonimbus clouds. They are formed when raindrops are subjected to forceful updraughts and are taken up and down several times through the freezing layers of a tall cloud. Each time they go up, more water freezes on to them until they are too heavy for the cloud and they fall out. When they fall they can be as small as grains of rice, and can do damage to crops and break windows. In rare cases, they can be as large as apples and extremely dangerous. The largest hailstone recorded fell at Coffeyville, Kansas, USA, on 3 September 1970. It weighed 0.75 kg and was 14cm across.

Thunder and lightning

If you are caught out in lightning, do not shelter under a tree, get away from metal poles such as electricity pylons and do not stand up or lie down — crouching is better. Get into a car if possible (it's safe); if you are inside a building, stay away from the walls.

How a thunder cloud — a tall cumulonimbus, typically with an

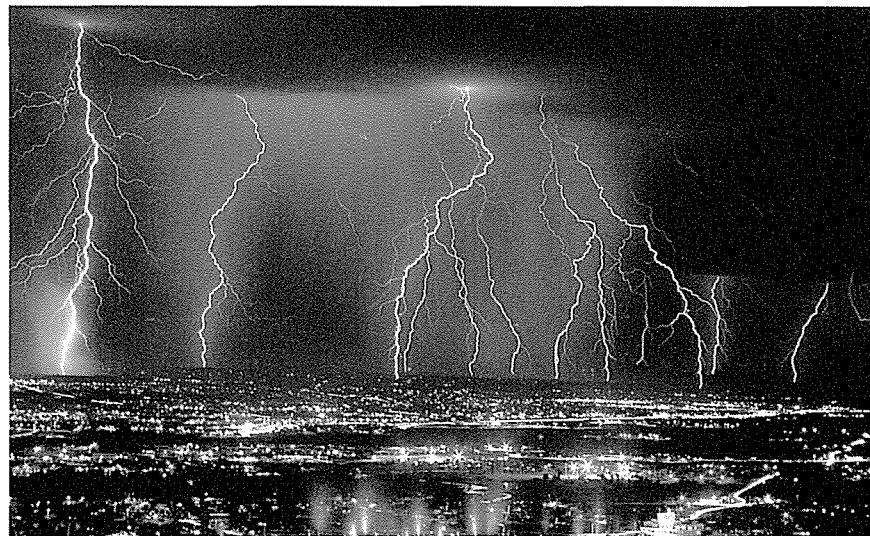
the charge is equalized by a bolt of lightning (a giant spark) linking the oppositely charged areas. Most lightning occurs within clouds (where it cannot be seen) but it also goes from the earth to the cloud (where it is easily visible).

Contrary to what seems to happen, the lightning actually strikes up. There is a small down stroke, called the leader stroke, that acts as a guide for the main stroke. Following the track of the guide stroke, the main return stroke shoots up to equalize the charge between the



This thundercloud, illuminated by a flash of lightning, was photographed by the Space Shuttle Discovery. Most lightning is not usually seen.

Waterspouts are whirlwinds extending down from cumulonimbus clouds. They form over seas and lakes, mainly in tropical regions. They churn up the water into a spiral that can be anything from a few metres high to a few hundred metres high and last for about 30 minutes. The most spectacular waterspout ever recorded rose over 1,500 metres and measured over 30 metres across.

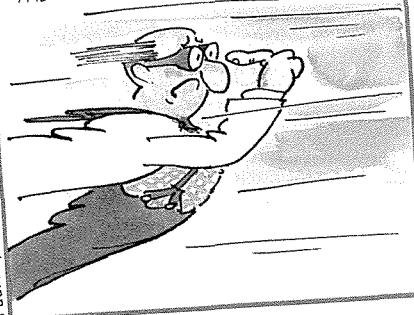


Telegraph Colour Library

Just amazing!

HIGH-SPEED TRAVELLER

NO ONE HAS YET MANAGED TO MEASURE THE SPEED OF THE WIND INSIDE A TORNADO — IT'S SO FAST IT DESTROYS THE EQUIPMENT. ESTIMATES PUT THE FASTEST TORNADO AT 725–805 KM/H.



Paul Raymond

anvil-shaped head — builds up the huge electrical charge necessary for a lightning bolt is not fully understood. Ultimately, however, the power comes from the upwelling of warm moist air into cooler air. As moisture condenses out, it gives off heat and water droplets gain kinetic energy as they fall.

The falling and rising of small frozen water particles, ice particles and water droplets seems to create sections of the cloud that are negatively and positively charged. When the difference in charge between the negative and the positive sections of the cloud is great enough,

Flashes of lightning occur about 6,000 times every minute throughout the world. The flashes travel from clouds to the ground, taking the easiest route possible, often a tall tree or high building — the Empire State Building, in New York, is hit about 500 times each year.

earth and that found in the lower parts of the cloud.

The temperature within a flash of lightning is around 30,000°C. This is enough to heat the air up so much that it expands explosively, creating the bang that is heard after the bolt.

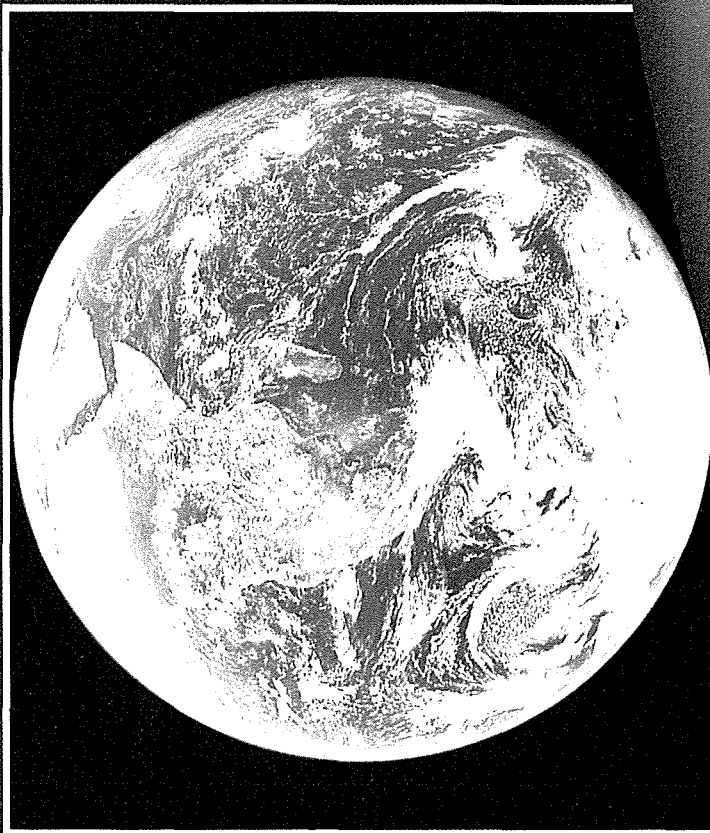


SUN POWER

AIR CURRENTS

CORIOLIS EFFECT

UNDERSTANDING WEATHER



NASA

A rainbow-like sunrise over the sea, as seen from the Space Shuttle. Uneven heating of the Earth by the Sun, combined with the effects of the Earth's spin, produce complex, swirling air currents. These are clearly displayed in the cloud patterns pictured from space (inset above).

BESIDES KEEPING US WARM, the Sun also supplies the energy to drive the Earth's powerful and complicated weather systems. Wind, rain, snow, hail, fog, frost, heat and cold are the ground-level effects of the Sun's heat on our planet's air, water and land at different latitudes.

The Sun radiates colossal amounts of energy. A great deal of this radiation is visible light. The

Sun also pours out other types of electromagnetic radiation, such as ultraviolet rays, radio waves and x-rays. When this radiation hits the Earth's outer atmosphere, it has the power of about 1 kW per square metre. If perfectly collected, the solar radiation falling on a square with sides of 1 metre would boil the water in a 1.7 litre kettle in about ten minutes. The total power reaching the Earth from the Sun is about 100 million million kW. That is more than one hundred thousand times the power produced by all the power stations of the world.

Nearly half of this radiation is either absorbed by the atmosphere

or reflected by it back into space. When the radiation that reaches ground level hits land, sea, a tree, building, sunbather or whatever, it is absorbed and changed into the infra-red (heat) radiation that we feel.

When the Sun is directly overhead, as in the tropics, on average each square metre receives about half a kilowatt — enough to power about eight reading-lamp light bulbs. Closer to the poles, where the Sun is shining at an angle to the surface, the Earth receives only about one third as much energy on average.

Balancing heat

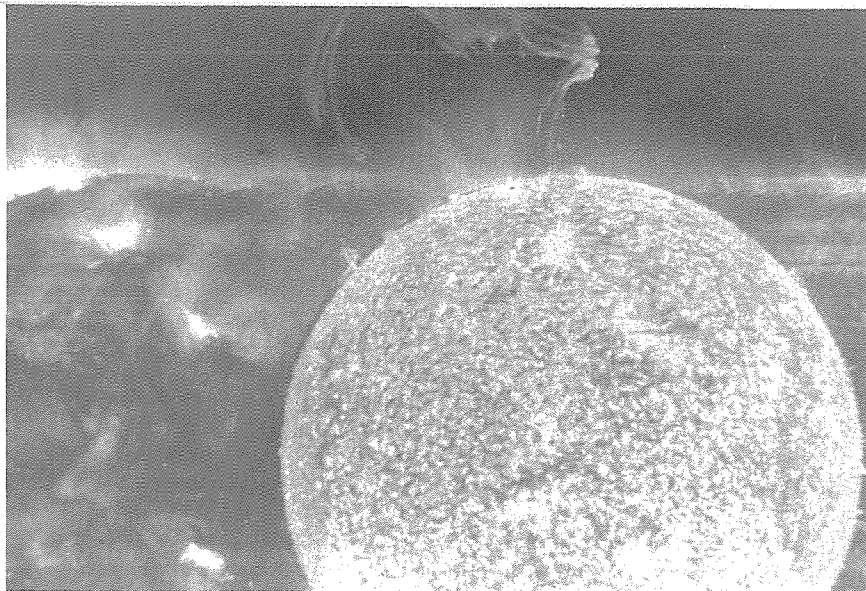
If there were no winds, the poles would get very much colder and the equator would get incredibly hot.



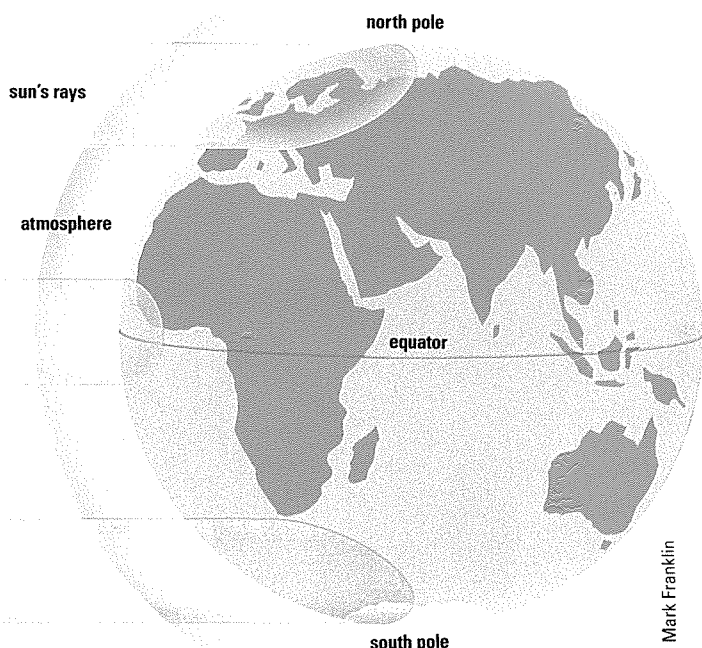
Fortunately, the winds carry hot air away from the tropics and cold air away from the poles. How the winds come to blow is the key to understanding the weather.

The troposphere

Almost all the activity happens in the bottom layer of the atmosphere, which is called the troposphere. This is about 18 km deep over the equator and 8 km deep over the poles. In the troposphere, the air is swirling about and this is where most of the heat redistribution takes place. The atmosphere is held down to the Earth by the force of gravity, and the weight of all the air makes up atmospheric pressure.



Telegraph Colour Library



Mark Franklin

Blazing hydrogen prominences shoot out from the Sun as it generates enormous amounts of energy. Some of this energy reaches the Earth and powers our weather systems.

The Sun's rays that reach the polar regions travel further through the atmosphere; they also spread out over a larger area of land. This is why the heating effect at the poles is much less than at the equator.

The first stage of heat redistribution occurs when the air near the equator heats up. Air expands and becomes less dense when it heats up and so it rises. This leaves a reduced pressure on the surface of the Earth below. As a result, cooler air from nearer the poles is sucked

in to replace the air that has risen. This movement of air is felt as wind.

The large volumes of air that rise from the areas around the equator eventually reach the top of the troposphere. They then move towards the poles, becoming cooler all the time. Meanwhile, the cool air

arriving near the equator heats up and starts to rise.

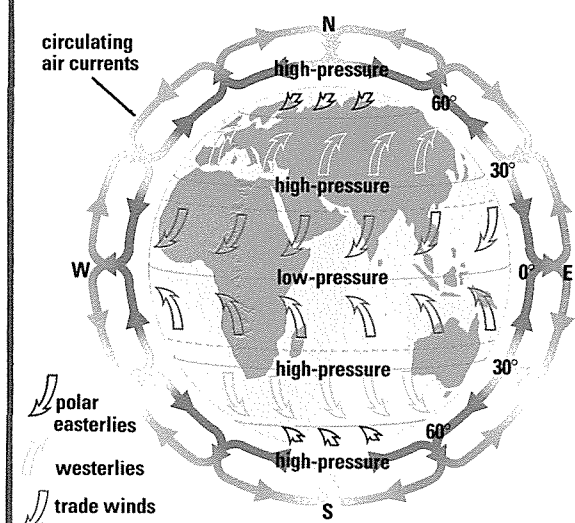
In the tropics, warm air rises in a band extending about 10° either side of the equator. After moving away from the equator, this air descends around latitudes 30° north and south of the equator. The cool air replacing the warm air does not come directly from the north and south, as the rotation of the Earth deflects the winds. This is called the Coriolis effect.

Wind belts

When the Coriolis effect acts on the cool air approaching the equator, it gives rise to the winds known as the north-east and south-east trades. The air that descends around 30° north and south of the equator causes regions of high pressure. Some of this air returns to the equator, while some moves towards the poles. The latter gives rise to winds which, because of the Coriolis effect, blow from the south-west and north-west. These winds are known as the westerlies.

In the northern polar region, cold winds blow from the north-east: similar winds blow from the south-east in the southern polar region. These are the polar easterlies.

WHERE THE WINDS BLOW



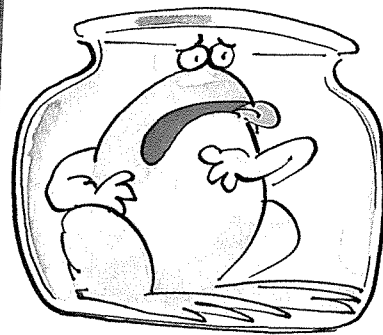
Circulating air currents in the atmosphere produce winds over the Earth's surface. As the Earth spins, the equator and the air above it move round fastest of all. Because of differences in spin speed, air moving towards the equator is turning too slowly towards the east to keep up with the Earth's spin there – so this air appears to be deflected towards the west. Air moving away from the equator is moving faster than required to keep up with the Earth's spin nearer the poles, so it appears to be deflected towards the east.

Mark Franklin

Just amazing!

CROAK... CROAK...

A STRANGE KIND OF BAROMETER WAS ONCE POPULAR IN GERMANY. A LIVE FROG, KEPT IN A JAR, WOULD CROAK WHEN THE AIR PRESSURE DROPPED.



Paul Raymond



elements in action

Richard Howes/Meteorological Office

AIR MASSES

DEPRESSIONS

CLOUDS

ON A GLOBAL SCALE, THE weather is a giant heat redistribution machine powered by energy from the Sun. The resulting winds and air masses have different temperatures and humidity. Where they meet, they form weather systems, such as depressions and anticyclones.

Air masses are very large quantities of air that have approximately the same temperature and humidity throughout. They are created over sea (maritime), large areas of land (continental) and over the poles (arctic and antarctic). These air masses are further broken down into warm (tropical) and cold (polar) types. So a polar continental mass would be one made up of a uniform mass of cold air formed over a large land area, while a tropical maritime mass would be one made up of warm air formed over an ocean.

Typically, air masses formed over oceans contain more water vapour than those formed over continents. Warm air masses also contain more water vapour than cold air masses.

Thus a tropical maritime air mass has warm humid air, while a continental polar mass has cold dry air. Polar air masses also create higher pressure beneath them as the cold air is denser. Tropical air masses create lower pressure beneath them because the warm air is less dense.

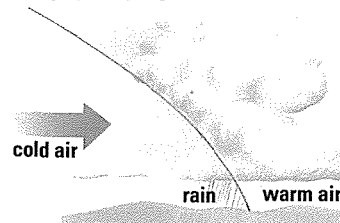
Air masses are pushed or dragged along by the winds. As they are

***Alternate layers** of moist and dry air, forming over a mountain range, produce the lenticular (lens-shaped) cloud formation known as altocumulus lenticularis. This type of layered formation is also known as a 'pile of plates'.*

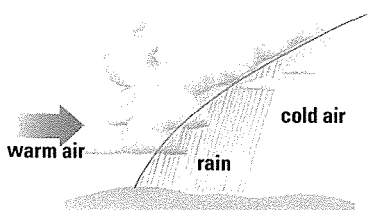
FRONTS – AIR STREAM BOUNDARIES

At a cold front, advancing cold air cools a mass of warm air, forming clouds. These typically produce a zone of heavy rain about 80 km wide, followed by a 320 km zone of showers. At a warm front, advancing warm air cools as it rides up and over a cold air mass. The resulting clouds typically give a 320 km zone of rain or snow. When a cold front overtakes a warm front, clouds form in the occluded (cut-off) warm air, giving widespread rain.

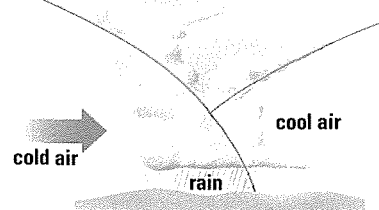
Cold front



Warm front



Occluded front

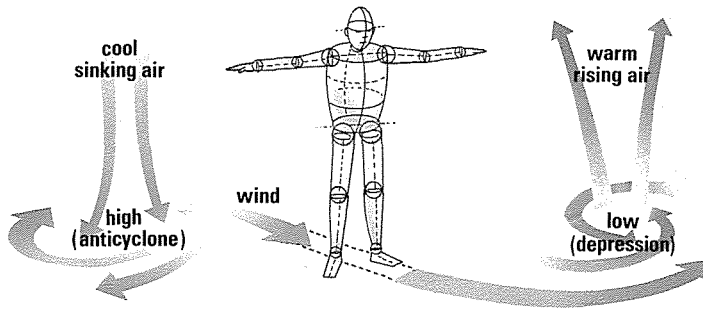


Chris Forsey



PRESSURE DIFFERENCE – THE CAUSE OF THE WINDS

The pressure difference between a high-pressure zone (anticyclone) and a low-pressure zone (depression) causes a wind to blow between them. The Earth's spin makes the wind spiral out from the anticyclone and into the depression. In the northern hemisphere, if your back is to the wind, the depression is always to your left; in the southern hemisphere, where the winds are reversed, it is always to your right.

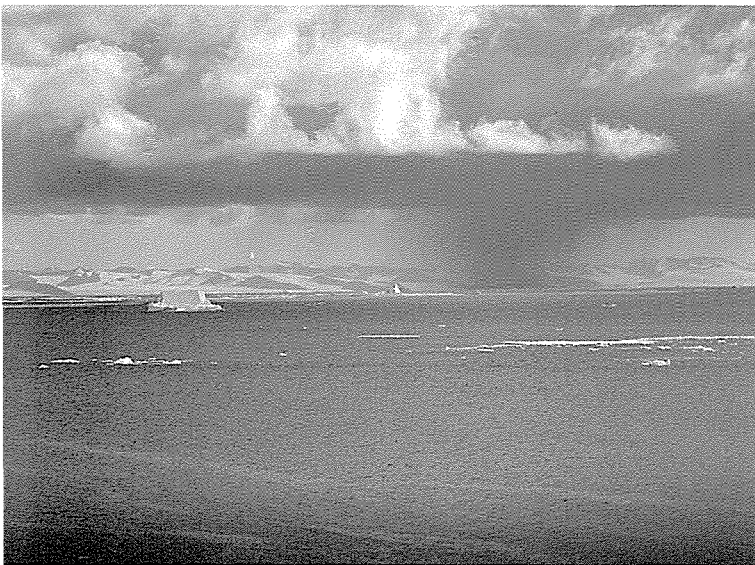


Chris Forsey

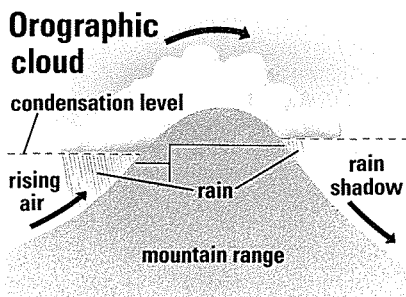
A snow shower sweeps across the Antarctic mountains, driven by the cold winds that blow from the South Pole and curve to the west.

are called polar fronts. These regions of contact are where unsettled weather occurs.

Unsettled weather with stormy winds and rain is brought about by the depressions, or low-pressure regions, that the weather forecasters talk about on TV. These are



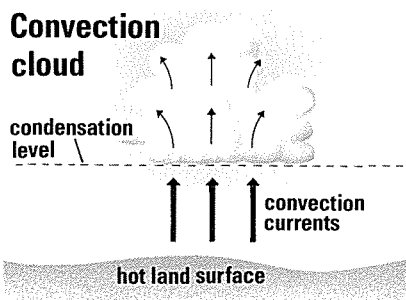
Kim Westerskov/Oxford Scientific Films



Clouds settle in an inversion layer if the air temperature increases with height. They cannot rise any further as the air above them is less dense.



GSF Picture Library



moved, they take on some of the character of the surfaces over which they travel.

The cold air masses from the higher latitudes are continually moving down towards the lower latitudes. Meanwhile, the tropical masses are moving up from the middle latitudes. The junctions between different air masses are called fronts. The fronts that mark the boundaries between the polar air masses and the tropical air masses

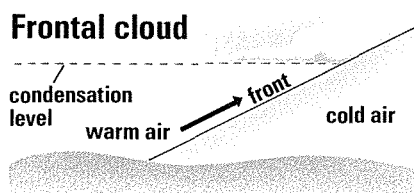
Orographic (mountain) cloud forms when moist air is forced up the side of a mountain. The cloud produces rain or snow on the windward side, while the sheltered side is relatively dry. **Convection cloud** forms when warm air rises from a hot land surface or when cold air crosses a relatively warm sea. **Frontal cloud** forms when warm air rises above cold air at a warm or cold front.

formed when a tropical air mass bulges into a polar air mass, thus buckling the polar front. The warm tropical air mass, being less dense, rises over the cooler, denser polar air. This rising air causes the air pressure to be reduced under the bulge. The cold dense air races towards the area of lower pressure and, because of the Earth's spin, begins to spiral around it. The spin of the Earth on its axis makes the cold air move anticlockwise in the northern hemisphere and clockwise in the southern hemisphere.

Changing fronts

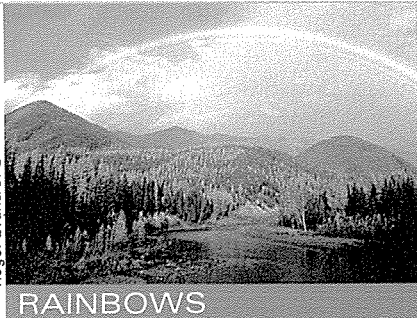
As the front of warm air continues to ride up and over the cold air, the pressure drop is greatest immediately below the advancing tip of the warm front. This marks the middle of the depression. Meanwhile, the cold air front swings around behind the warm air bulge, undercutting it.

In time, the cold front catches up with the warm front and cuts off the bulge of warm air above it from the main part of the tropical air



Chris Forsey





RAINBOWS

Rainbows form when raindrops split sunlight into bands of colour. In a clearly formed rainbow, seven distinct bands of colour can be seen: red, orange, yellow, green, blue, indigo and violet. Sun light consists of a mixture of different coloured rays and each colour is deflected through a different angle by the rain drops. Therefore rays of a particular colour reach us from only a small group of raindrops. People in different positions see the rainbow in different places, though it is always on the same side of the sky to the Sun.

mass. When this happens, what is known as an occluded (closed-off) front is formed, and the air pressure below starts to rise. The isolated region of warm air gives up its heat to the cold air and mixes with it, so the pressure below rises again.

The opposite of a depression is a high-pressure region, or anticyclone. These come about in areas where the air is descending. Descending air warms up and tends to absorb water droplets — so it removes any clouds from the sky. Areas of high pressure usually produce stable weather with clear skies, leading to hot sunny days in summer and cold days with hard frosts in winter.

How clouds form

Water vapour is an invisible gas and there is one essential rule about how much water vapour air can carry. The warmer the air, the more water vapour it can hold. When

warm, moist air cools, it sometimes reaches a point, known as the dew point, where it can no longer hold all its water vapour. Some condenses out into tiny water droplets, which form clouds, mist or fog.

You can see temporary clouds form when you boil a kettle of water. Close to the spout, you can see a clear zone of water vapour; further away, the water vapour cools and condenses to form the clouds of water droplets that we know as steam.

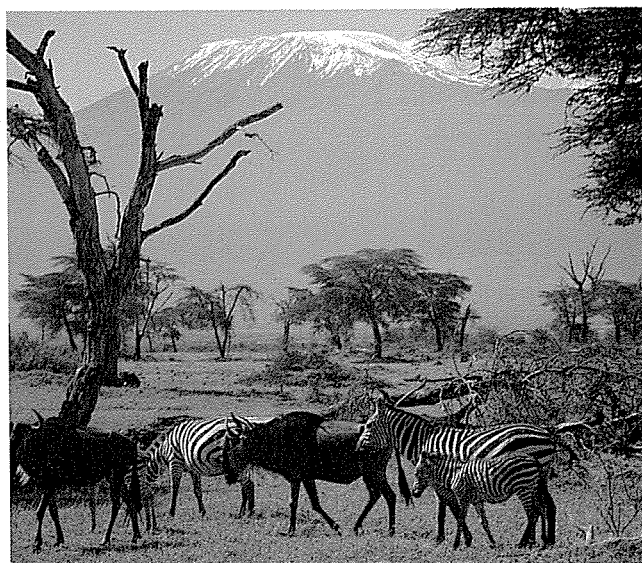
Rain and snow

A depression usually brings rain because the advancing warm air cools when it meets cold air. As it cools, its ability to hold water vapour decreases. So some of the water condenses out of the cooling air and forms either tiny water droplets or tiny ice crystals. These are seen as clouds.

The water droplets or ice crystals eventually bump into each other and join together. When they are too big to be held up by the air currents in the clouds, the droplets or crystals fall out as rain or snow. Sometimes the raindrops become

Tropical regions have snow on high ground. The warm Earth heats the atmosphere from the bottom, so temperatures are much lower than those at sea level.

Cloud names are based on their height and appearance. The three basic types are cirriform (wispy clouds), cumuliform (heap clouds) and stratiform (layer clouds).

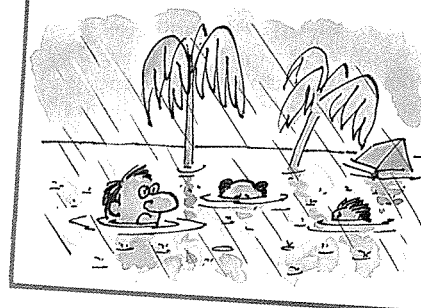


ELEMENTS IN ACTION

Just amazing!

WET... WET... WET

IN ONLY 24 HOURS, A RECORD 1.87 METRES OF RAIN FELL AT CILAOS IN THE INDIAN OCEAN ISLAND OF REUNION. IF IT HADN'T RUN OFF, THE WATER WOULD HAVE DROWNED EVERYONE UNDER 1.9 METRES TALL.

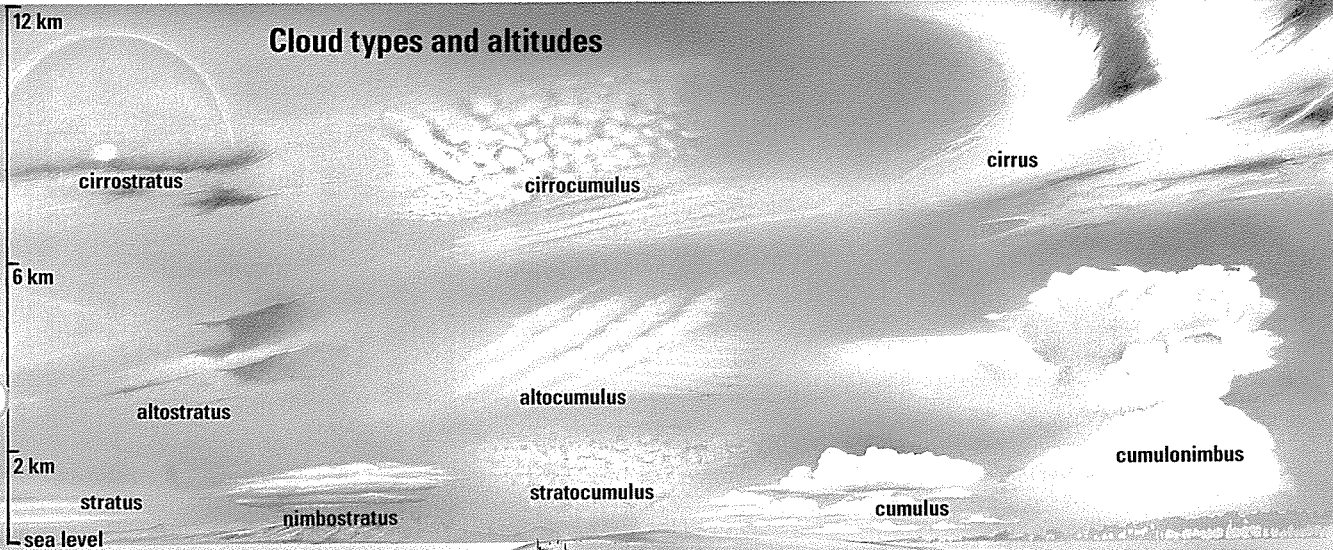


Paul Raymond

frozen and fall as hailstones.

Clouds are formed in a similar way when advancing cold air forces warm air upwards. Also, in an occluded front, the region of warm air loses heat to the cool air below, and vapour condenses as clouds.

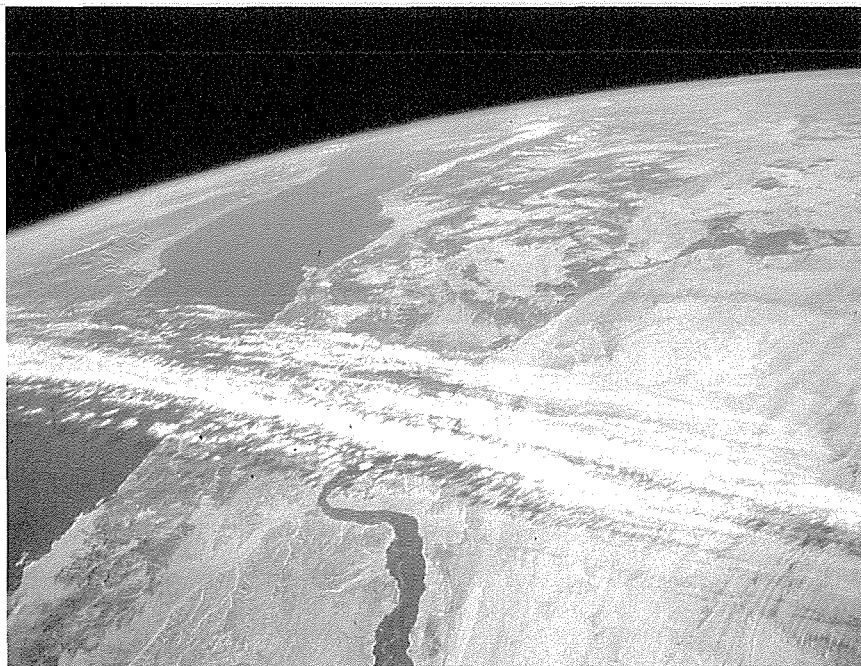
Cloud types and altitudes



On average, about half of the Earth is covered by clouds at any time – and it is not only when fronts mix that they form. Whenever air carrying water vapour cools below a certain temperature, clouds of water droplets or ice crystals form.

Clouds sometimes form when a wind carrying water vapour hits a mountain range. The wind is suddenly forced upwards, so it cools and water vapour condenses out to form clouds. This explains why mountain ranges are often very wet on the windward side and less so on the leeward (sheltered) side.

Another way for clouds to form is when a small bubble of air over a particularly hot piece of land is heated so that it rises through colder surrounding air. Eventually it



Telegraph Colour Library



Jet streams are high-speed, high-altitude belts of wind. A subtropical jet stream encircles the Earth and its path becomes visible when clouds form within it. A local jet stream is usually some thousand km long, a few hundred km wide and a few km deep.

Fog banks drift across the sand dunes along the coast of South West Africa. This occurs when moist warm air blows in from the sea in the early morning. The cold land cools the air, causing water vapour in it to condense to form clouds of tiny water droplets.

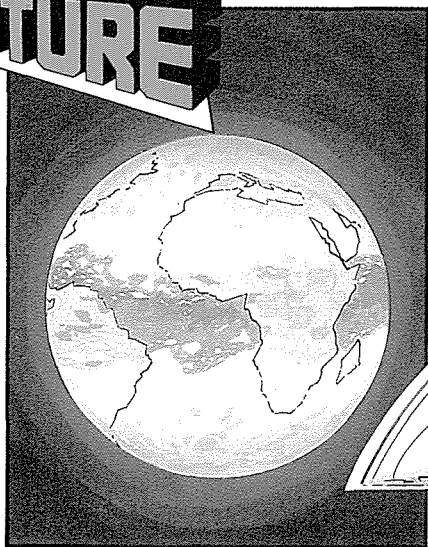
gets high enough to cool down to the point where water vapour condenses out to form a cloud. A typical example of this type of cloud is the fair-weather cumulus.

Fog and mist

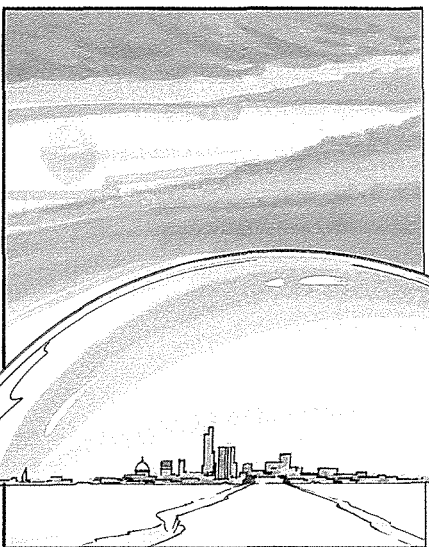
The sailor's curse and the motorist's nightmare, fog, like cloud, is formed when moist air cools and cannot hold as much water vapour. Typically, sea fog occurs when a warm, moist tropical air mass moves over a cold sea. Close to the water, the air cools and the water vapour that it contains condenses to form tiny droplets. Over land, fog occurs when air cools close to the Earth's surface and, again, water droplets condense. This often produces a morning mist when the land has cooled rapidly overnight under a clear sky.

INTO THE FUTURE

COPING WITH DRASTIC WEATHER CHANGES



▲ Variations in the Earth's orbit cause long-term changes in our weather. For instance, another Ice Age could occur sometime in the future.



▲ To combat the cold, cities in what are now temperate regions may have to be covered with plastic or glass in order to trap some of the Sun's heat.



▲ But if the Earth became hotter instead, the icecaps would start to melt. Barricades would be built around low-lying countries to prevent flooding.

Joe Lawrence



 TRANSPORTING OIL

 DANGEROUS LOADS

 IMPROVED DESIGN

A REVOLUTION HAS TAKEN place in the world's merchant shipping in the last 35 years. Huge tonnages of cargo are being moved faster, by a far smaller number of seamen and dock workers, than ever before.

Much of this cargo is carried by enormous ships that use on-board computers to co-ordinate satellite navigation information and data to plot the fastest, most economical routes across the ocean.

When the Suez canal was closed by war in 1956, Middle Eastern crude oil suddenly had to be transported around Africa to European refineries. This was a powerful stimulus to economize on transport costs by increasing the size of oil tankers.

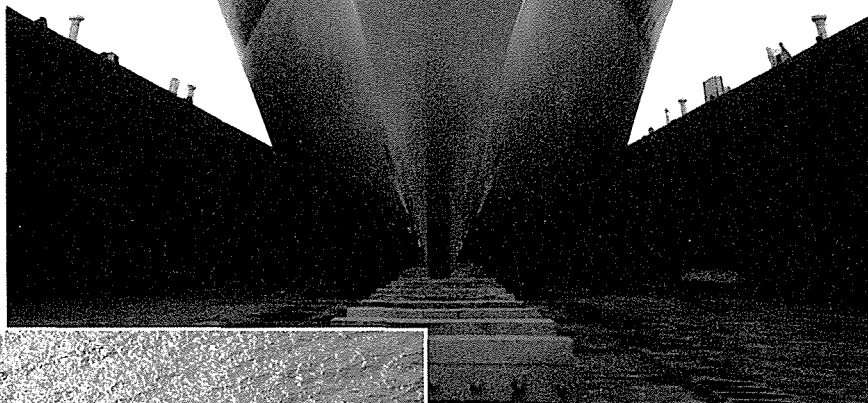
The supertanker

In 1959 the first tanker capable of carrying 100,000 tonnes of oil was launched. The size grew until ULCCs (Ultra Large Crude Carriers) capable of carrying over half a million tonnes were launched.

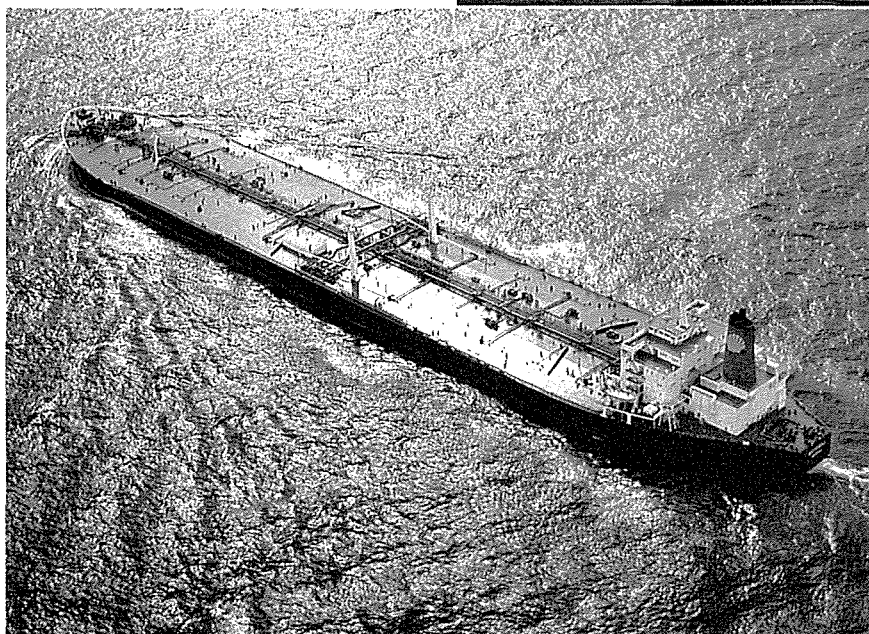
One of these monster ships will rarely encounter a port that it can enter. It moors offshore and pumps its cargo into smaller tankers — each of which would itself have counted as a giant 30 years ago. Or it pumps the oil into a pipeline leading from a buoy many kilometres off-shore.

A crew of perhaps 35 people can run one of these monsters. In fact, the ship can sail itself in the open sea, though not when it comes into coastal waters. The levels of oil in

THE CARGO CARRIERS



Flender Werft Aktiengesellschaft



New generation cargo ships sport a great bulge in the bow below the water line. This modifies the flow of water at the bow and helps conserve energy.

At 310,000 tonnes, the Japanese-built oil tanker SS Lanistes burns about 160 tonnes of fuel every 24 hours when moving at full speed.

all the tanks, the settings of valves, temperatures and such can all be read from instruments on the bridge.

The crew enjoy the highest standards of comfort to compensate for the weeks at sea, with accommodation far superior to that found in old

A Shell Photograph



cargo ships. They even use bicycles to get from one end of the deck to the other — after all, it can be more than 300 metres from bow to stern.

Ore/oilers

An oil tanker will return empty to the oilfields when it has discharged its load at the refinery, because the tanks cannot be cleaned out completely. In future, ships will be able to carry other sorts of cargo in the tanks on the return journey. Such vessels are called OBOs (oil/bulk/ore), or ore/oilers. Tanks running centrally along the length of the ship can carry either oil or a solid cargo. Other tanks flanking these carry either oil or ballast water.

Nevertheless, some heat eventually gets in, and this is allowed for by letting some of the liquefied gas boil off, at the rate of a fraction of one per cent every day.

Containers

Equally dramatic developments have taken place in the transportation of goods. Starting around 1960, the developed countries' docks and cargo fleets have been transformed. They have become one huge network to facilitate the flow of cargo in standardized containers. By international convention these are 2.4 metres wide by 2.4 metres high, and multiples of 3 metres long.

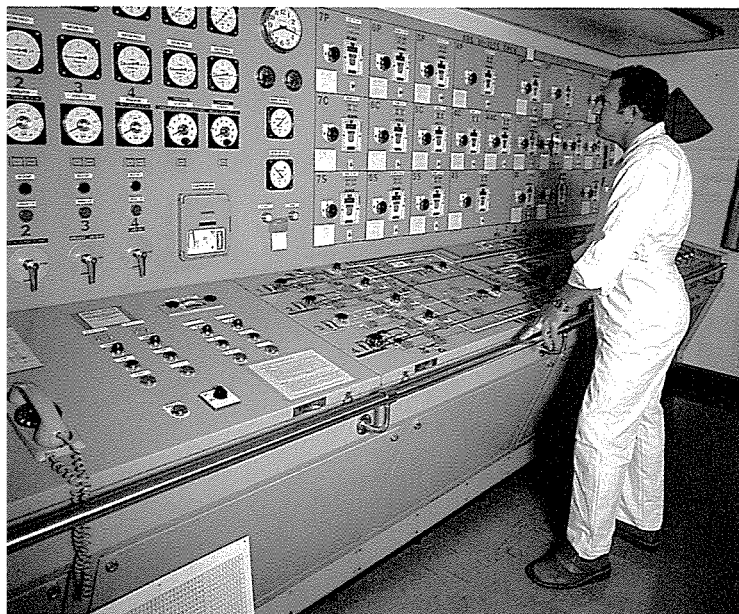
Almost any dry cargo whatever can be carried in containers, which are 'stuffed' where the cargoes originate or at special 'groupage' depots. Cargoes take up more space packed this way and each tonne may now occupy five cubic metres — more than twice as much as formerly. Nevertheless, a staggering increase of productivity came with containerization. Cargo handling in docks was speeded up by more than ten times, losses and damage were a tenth of their former values, yet all this could be carried out with only a third of the labour force.

The ro-ro ship

At one time, motor vehicles were loaded on to ships by cranes. During World War II, tank landing ships were developed: tanks could be driven straight on to and off these. After the war, some of these craft became the first ro-ro (roll-on roll-off) car ferries. But it was not until 1957 that the first purpose-built civilian ro-ro ferry was launched.

Short-distance ferries can load and unload through doors at both bow and stern: longer-range ships may be large enough to permit

Computerization is the key to low manning levels on these enormous vessels. Modern tankers normally have a crew of between 25 and 35. Smaller vessels with manual equipment need a bigger crew.



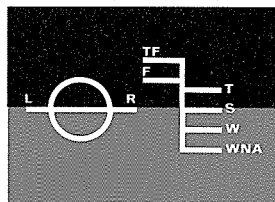
A Shell Photograph

Natural gas is a valuable product of the oil wells that is now transported by specialized ships called LNG (liquefied natural gas) ships. LPG (liquefied petroleum gas) ships use a combination of high pressure and low temperature to keep their cargo liquid. This processing is carried out at a plant on-shore.

To liquefy the gas, it has to be cooled below — 161°C. The liquid is kept in heavily insulated tanks.

Heavy insulation is used on LNG vessels to protect the liquefied natural gas from the relative warmth of the sea. The small amount of gas that does 'boil off' during loading is used to fuel the main boilers.

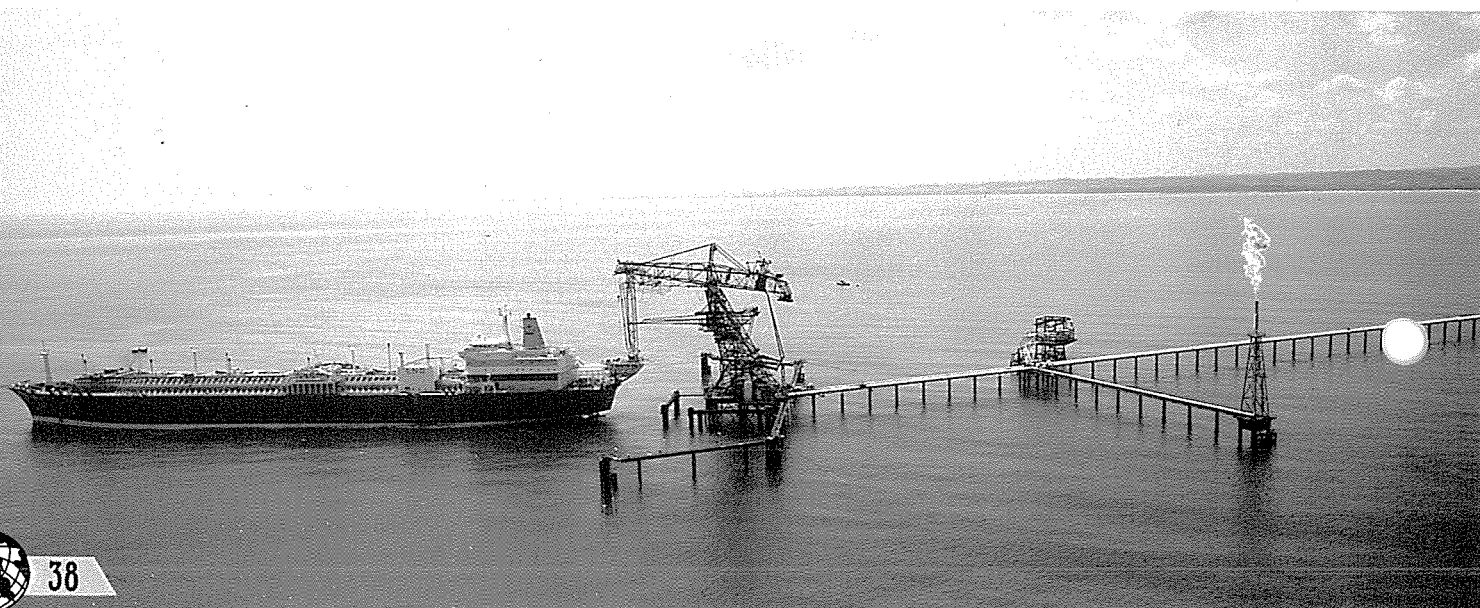
KEEPING THE SHIP IN LINE



Ships must not be loaded too heavily, or they will be at risk of sinking in heavy seas. The Plimsoll mark shows how deep in the water the ship may safely go. For a given load the ship will float higher the denser the water is. Salt water is denser than fresh, and cold water is denser than warm.

So there are various markings corresponding to different circumstances. The lines on the left marked F and TF represent fresh water and tropical fresh water respectively. The lines on the right all correspond to salt water: the letters stand for tropical, summer, winter, and winter North Atlantic. (The North Atlantic suffers from very heavy seas in winter, and the ship must be less heavily laden then.) LR stands for Lloyd's Register, the organization that makes shipping safety rules. The 'mark' was named after Samuel Plimsoll.

Trevor Vertigan



CARGO CARRIERS

Container ships carry cargo in their hull and also on deck. Any deck cargo must be properly secured, not only to prevent loss at sea but also to ensure the ship remains stable in heavy seas.

Cargo is loaded on to lorries directly from the ship, which considerably reduces the length of time a container ship has to remain in port. This method of transportation also reduces cargo damage.



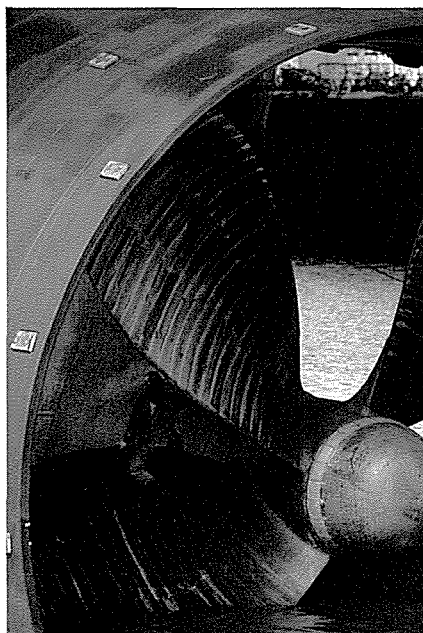
P & O Containers Ltd

Fotoflite

vehicles to manoeuvre, so there are doors at the stern alone. An adjustable ramp is required at the dock to form a bridge to the vehicle deck no matter how high or low the tide is.

Some ro-ro ships are loaded with trailers that are brought on by trucks that then drive off again. They are unloaded by other trucks at their destination.

Even in the jet age, ships are being constantly transformed by dramatic technological innovations. One design that is attracting excited attention at the moment is the SWATH (small waterline-area twin-hull) ship. In this the load-carrying structure is carried above water level by twin hulls, catamaran-style. The minimal 'wetted' area in the water minimizes drag.



Martin Rogers/Colonial

Roll-on roll-off car ferries opened up the rest of Europe for water-bound Britons. Doors at both bow and stern allow drivers to literally 'drive through' the vessel. Long range ferries often have only one opening, but are large enough to allow drivers to turn their vehicles around.

The ducted propeller, which has a ring around the blades, is used in preference to the open propeller. Being more efficient, it uses less fuel and, therefore, reduces operating costs.



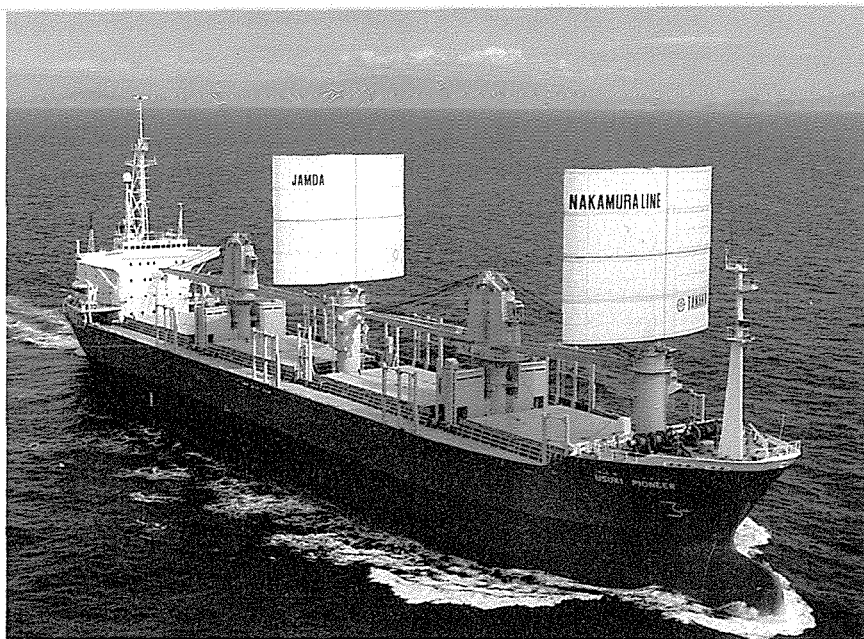
Sealink British Ferries Ltd

water — more than four times as much as for a typical tanker of the 1950s.

This improvement is due to a number of factors:

- Controllable pitch propellers, in which the angle of the blades is changed according to the ship's speed.
- Improved hull design. For example, a great deal of the energy used by a ship goes into making waves. Now all large modern ships have a





Daudier/Jerrican

bulge at the bow beneath the waterline. This reduces the size of the bow wave, and hence reduces the energy wasted.

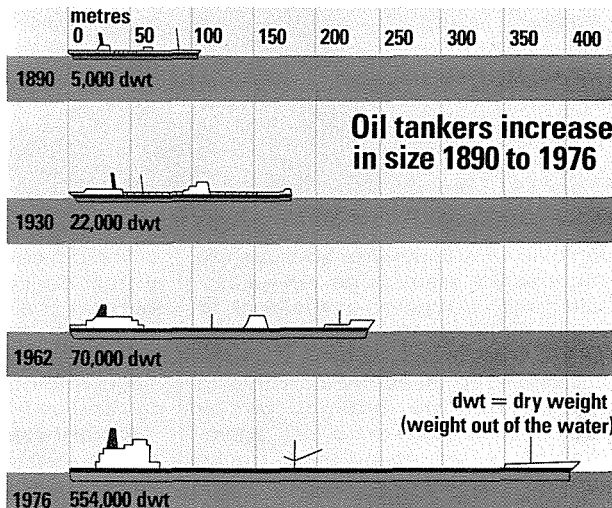
- Ducted propellers. These incorporate a ring around the propeller and are more efficient than open propellers.

Building methods

Along with the revolutions in the design of ships and in the work they do, there has been a revolution in the method of building them. Formerly workmen jostled in the confined space of the ship's hull, at the mercy of the weather, as it was built on the slipway from which it would be launched. Now prefabricated sections are built in covered

The first fully automated sail-assisted ships – Usuki Pioneer shown – had two rigid masts. The sails are controlled by a computer and can be folded when wind conditions are not favourable.

Ultra large crude carriers, weighing over 500,000 tonnes, were built in the mid-70s; a change in the oil market since then has meant tankers are unlikely to be larger.



Mark Franklin

THE SEMISUBMERSIBLE SHIP

An important modern type of ship is designed to be sunk – or half-sunk, at any rate. Called the semisubmersible ship, it solves the problem of getting heavy loads on board. Tanks on the ship are flooded and it sinks until just its bow and stern superstructures are above the water. The load is then floated over the centre section and the tanks are pumped empty; the ship rises again, lifting its new cargo.

In the LASH (lighter aboard ship) system, barges (called lighters) are floated on to a semisubmersible mother ship. They can then be carried across oceans and floated off to continue their journey on inland waters. Cargoes are carried between the Mississippi and the Rhine in this way.

Semisubmersible ships can be used to pick up damaged ships for transport back to a ship repair yard.

cally reset as they turn the wheel.

Sails are not the only way of getting help from the wind. Vessels can be towed by kites. Rotating vertical cylinders – in the air, the water, or both – can also generate forces that can be used to help a boat along, or to steer it, with less energy loss than an ordinary rudder.

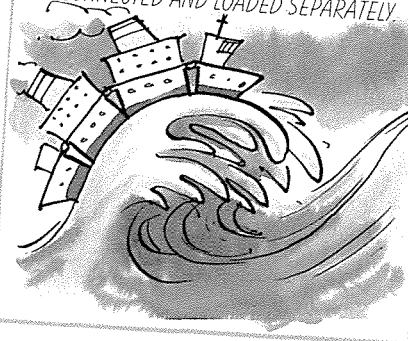


Fotoflite

Just amazing!

JET AGE SHIPS

ONE OF THE FIRST LARGE CARGO SHIPS, A 19TH CENTURY SHIP CALLED THE CONNECTOR, HAD THREE OR FOUR HINGED SECTIONS TO LET HER RIDE THE WAVES MORE EASILY. EACH SECTION COULD BE DISCONNECTED AND LOADED SEPARATELY.



Paul Raymond



- ☐ COMMUNICATING IN
- ☐ EAVESDROPPING ON
- ☐ BEAMING MESSAGES

WATER BARRIERS

Earth dams are built using a network of temporary roads for the tipper trucks and bulldozers to move around on.

Spillways on the Hoover dam in the USA lead surplus water off into side valleys, then away through tunnels cut in the rock.

THE POWER TO TAME RIVERS, control torrents and drive back the sea is given to comic book superheroes at the time of their birth. The rest of us need dams, locks and sea walls to accomplish the same feats. Dams are the commonest man-made water barriers.

Dams are built across rivers for one or all the following reasons:

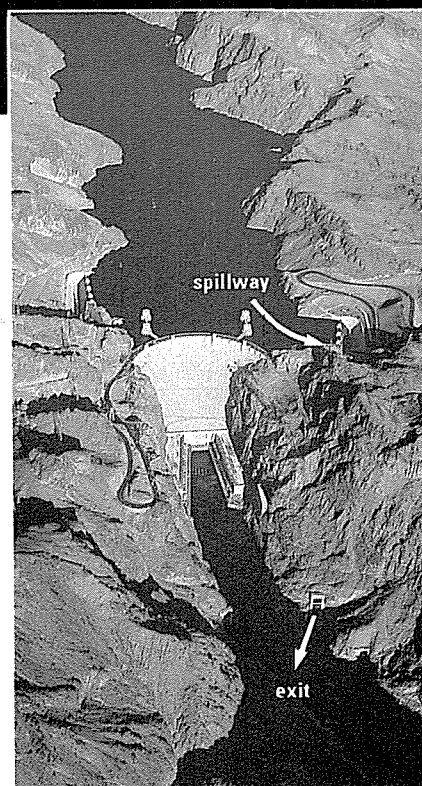
- To create reservoirs
- To generate electricity
- To feed irrigation systems
- To control floods.

The colossal Nurek Dam on the Vakhsh River in Tadjikistan in the Soviet Union stands 317 metres high and is 730 metres long. It provides hydro-electric power for

the local people, plus irrigation and drinking water for an area of more than 10,000 sq km.

Dams are built in one of two ways. They are either made of rock and earth fill or of concrete. Rock-and-earth fill dams have to be much thicker than concrete structures because they depend on sheer weight for their strength, rather than the structural properties of reinforced concrete. They are mainly used to create irrigation reservoirs in relatively flat and wide river valleys.

Earth dams can also be far bigger than concrete ones. The largest one in the world is the Pati dam on the Pavana River in Argentina, which is 174.9 km long, 36 metres high and is made of 238 million cubic metres

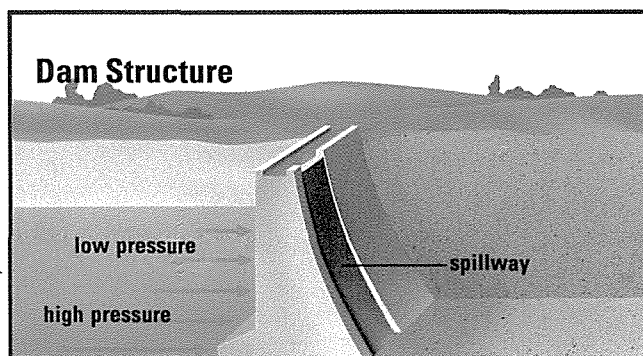


Spectrum Colour Library

of compacted earth-and-rockfill.

For comparison, the largest concrete dam in the world is the Grand Coulee Dam on the Columbia River in Washington State, USA. This is 1,272 metres long, 167 metres high and 8 million cubic metres of concrete were poured into the structure during construction. Typically, concrete dams are built across narrow valleys, where the ends of the dam can be securely anchored on the rocky sides of the valley.

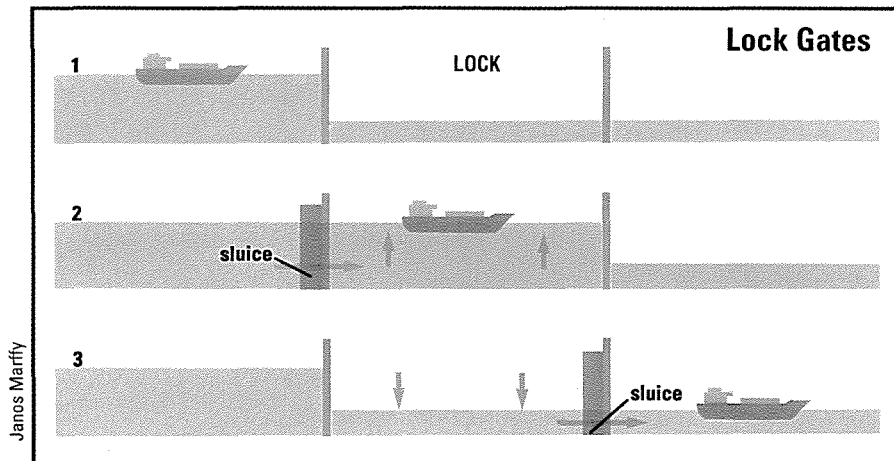
Whatever the design of a dam, it must be broader at its base than at its top. This is because the pressure of water against the face of the dam increases with depth. A sluice or spillway is always built into the design so that, when the water level is close to the top of the dam, water can be let out of the reservoir. If the water was allowed to simply overflow, it might easily undermine the dam and cause it to collapse.



Dams are always built with a broad base to withstand the higher pressure of deeper water. Spillways, normally built into the sides of the dam, allow surplus water to be drawn off by the dam engineers. The overflow is controlled by electric sluices.

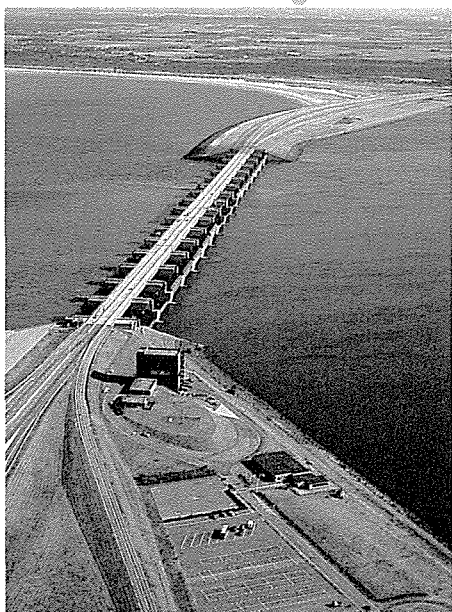


Lock Gates



Janos Marffy

The Delta Works in Holland are 30 km long and control the rivers Scheldt, Rhine and Maas. They also generate electricity and keep the sea out during storms.



Steve Kaufman/Bruce Coleman Limited



Twin locks on the Panama Canal allow ships going in opposite directions to bypass the water barriers without delay. Locomotives haul the ships through the lock.

Netherlands Board of Tourism

The designers and builders of large dams carry a heavy responsibility: if a big dam breaks, thousands of people and animals could be drowned and the devastation to communities could equal that of a natural disaster.

The sea is the other great mass of water that man sets out to control. Natural areas of sheltered water, where ships can seek refuge from storms and unload their cargo, are usually extended and improved with harbour walls. Where possible, harbour walls are built out into the sea from opposite sides of the harbour, leaving only a narrow entrance giving access to the open sea.

Soft shorelines

Where the shoreline is made of soft rocks such as chalk or clay, the sea will erode it by up to 10 metres a year. If a soft cliff is reinforced at the base with a concrete sea wall, the erosion can be halted. Where the shoreline is made of pebbles or sand, sea walls often have to be replaced every 30–50 years as the loose material they are built on shifts around, leaving the sea wall too weak to resist winter storms.

Another form of barrier against the sea, used to protect low-lying

1 A lock is sealed at either end with pivoting gates. **2** Before a vessel can enter, the water level in the lock is equalized with the level outside; this is done by opening the sluices in the base of the gates. **3** The process is repeated at the other end of the lock, so the vessel can sail on. Lock gates always open towards the deeper water – the water pressure forces them together, improving the seal.

land, is a dyke. Where areas of standing water are enclosed by dykes, the water is pumped out to form a 'polder' – an area of reclaimed land.

The most spectacular inland water barriers are rapids and waterfalls. Locks allow cargo ships and boats to bypass such barriers. They permit ships to transfer easily from one water level to another. Flights of locks – where one lock leads straight into another – allow ships to get over some quite high mountain ranges.

DAM DISASTERS



Popperfoto

Dams in earthquake zones are a potential danger to people downstream but disasters can also be man-made. The big dam at Fréjus in the south of France collapsed in 1959 sweeping away part of the town and killing over 300 people. The dam took eight years to build and cost £580,000; it was the thinnest structure of its kind. Damage was estimated at over £1,500,000. A geological fault had weakened the rock structure.

Just amazing!

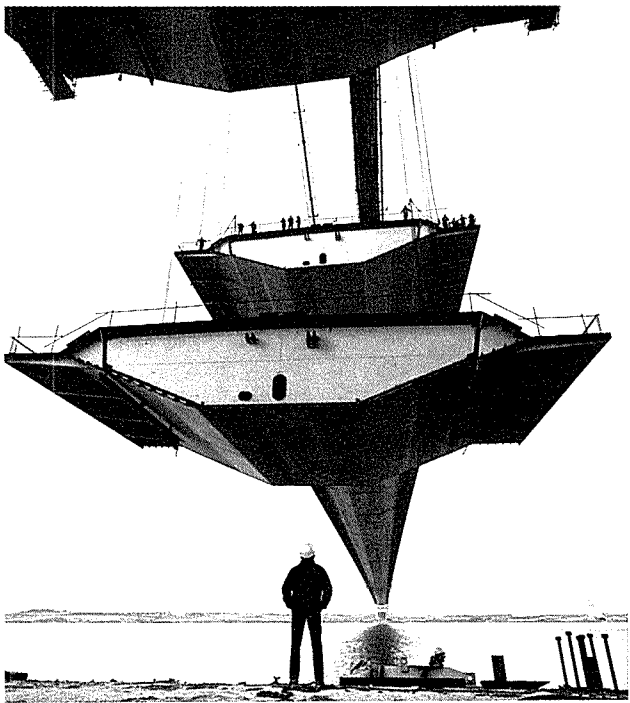
GIANT WATER WAY

THE LONGEST CANAL SYSTEM IN THE WORLD RUNS FROM NEAR-DESERT AT ASTRAKHAN ON THE CASPIAN SEA UP TO LENINGRAD ON THE FROZEN BALTIC. THIS IS 2,300 KM – FIFTEEN TIMES THE LENGTH OF THE SUEZ CANAL



Paul Raymond





Donald Innes Studios

- STRONG STRUCTURES
- BORE AND BLAST
- TUBE WORKS

The world's longest existing span suspension bridge – the Humber Bridge in North England – is built to withstand enormous forces. The deck is made of trapezoidal (quadrilateral) hollow box girders which were towed on pontoons and raised into place one at a time (inset).

Donald Innes Studios

BRIDGES AND TUNNELS



SPANNING OBSTACLES OVER and underground, modern bridges and tunnels are some of the most daring and beautiful structures ever devised by engineers.

There are several different designs of bridge, but they all share certain common problems. A bridge should be strong enough to support itself and the traffic that crosses it in any weather conditions.

The simplest kind of bridge to build is one that can cross the obstacles in one span. However, such bank-to-bank bridges can only link short distances, as they are limited by the length of the largest available steel and concrete girders. Most bridges, therefore, need supporting pillars built at some point along their length.

Suspension bridges

The longest bridges in the world are suspension bridges. In this design, the bridge deck hangs from thick steel cables which stretch from one bank to another, up over huge supports. The deck is attached to

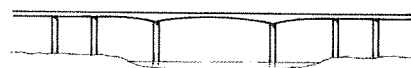
the cables by steel wires under high tension.

Where a bridge crosses a river or a stretch of water, there is the immediate problem of building a support underwater. This is solved by using a cofferdam, a watertight enclosure that is towed out to the point where the support is to be built, sunk and then pumped clear of water. The river bed must then be excavated down to bedrock or other strata strong enough to support the load-bearing pillars.

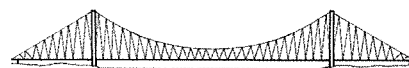
The 'cantilever' principle, whereby props from the main supports hold up the deck, can extend the single-span considerably. However, while a cantilever bridge does not strictly need supporting columns along its length, it does usually require intermittent 'props'.

Sometimes bridges need to be built where they would interfere with the passage of ships up and down a waterway. An alternative to tunnelling under the water is to build a moving bridge, all or part of which can be moved to allow ships pass through. Swing bridges, for exam-

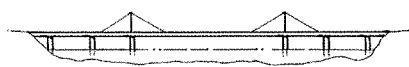
Basic Bridges



beam



suspension



cable-stayed



arch



cantilever

Chris Lyon

ple, have movable sections that swing aside horizontally to let ships pass through.

Cable-stay, steel truss, girder and beam bridges have different means of support, but in most cases, the weight is carried ultimately by the supporting columns. The fewer the columns, the greater the load they have to bear; on any bridge, about 90 per cent of the total weight it has

PROFILE BRIDGES

New building techniques and materials mean that bridges can now be made even longer, wider and higher than before.

Longest span

Humber Estuary Bridge, England, UK
1,410 metres
Akashi-Kaikyo Bridge, Japan,
(to be completed 1998)
1,980 metres

Widest

Sydney Harbour Bridge, Australia
48.8 metres

Highest

Royal George Bridge,
Arkansas River, USA
321 metres above water level

Tony Stone Photo Library, London

Spectrum Colour Library



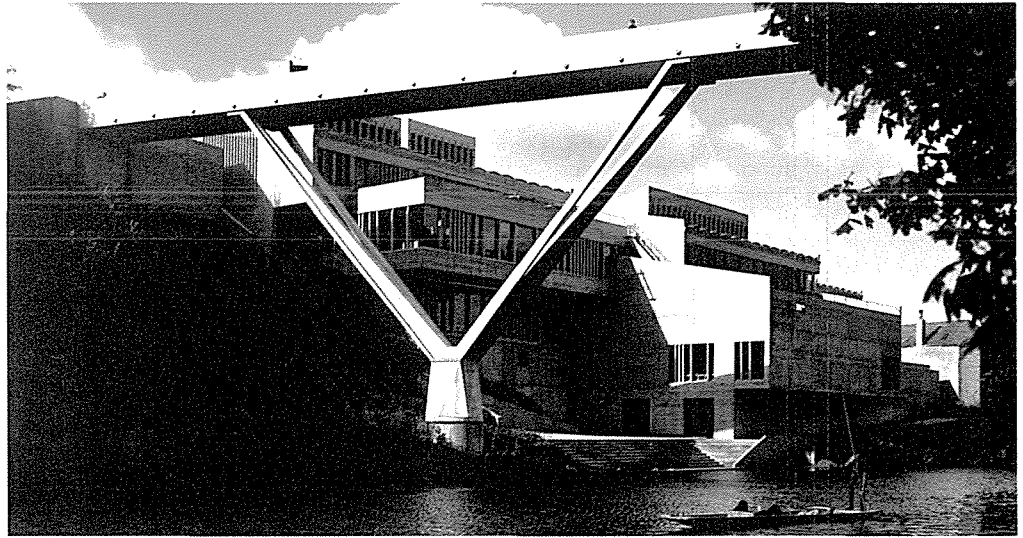
Downtown Chicago must use all possible routes for traffic, including the river. Bascule bridges – like London's famous Tower Bridge – raise their decks on pivots that glide on rails, thus making the river navigable inland.



The steel arch bridge over Sydney harbour, Australia carries both road and rail traffic. Capable of taking very heavy loads, it was tested with the weight of 72 locomotives – a total of over 77 tonnes.



The slim-line Kingsgate footbridge in Durham, England, designed by Ove Arup, is a fine example of the use of concrete. Two braced V piers support a continuous U-shaped girder, using an absolute minimum of materials.



George Wimpey PLC

Two arms reach out to meet each other and complete a box girder bridge. The box girder principle, so popular today, is used in both steel and concrete bridges. Box girders can come in a variety of cross-sections.



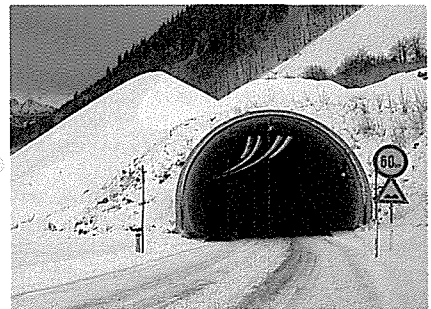
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to carry will be contained in its own structure.

Apart from ensuring that a bridge has sufficiently secure foundations and structural components to carry its own weight, engineers also have to consider the impact of winds blowing into the bridge sideways. They do this by testing models in

Four tunnels under construction for the New York subway. Underground rail tunnels are usually made by the 'cut and cover' method.

In drive-through tunnels, lighting is bright at the openings, so that drivers are not blinded on entering the tunnel nor dazzled on leaving it. Inside, the lighting is dimmed, as cars keep their lights on in tunnels.

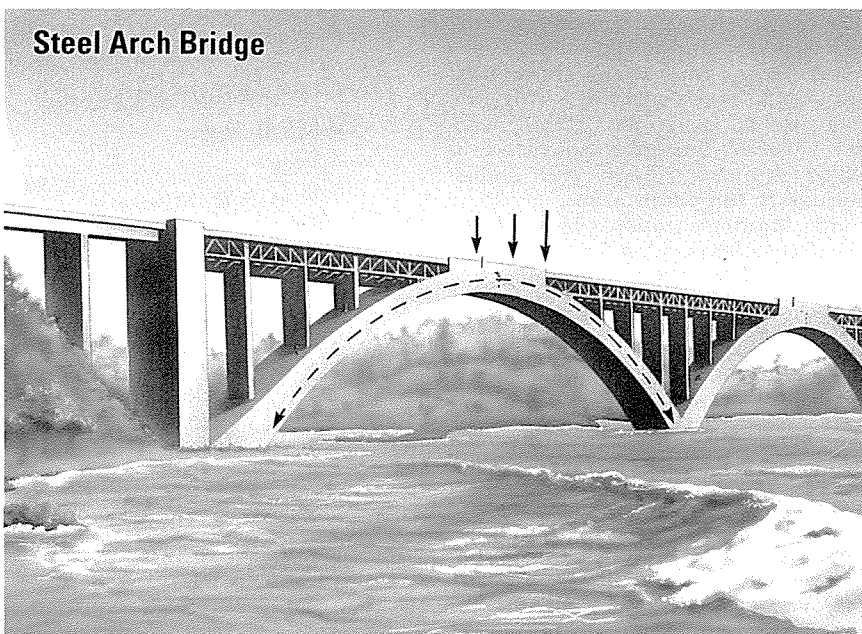


Spectrum Colour Library



New York City Tourist Authority

Steel Arch Bridge



Chris Lyon

wind tunnels to assess the necessary lateral stability. Many of these tests can also be simulated on computers.

Wind shields can also be built on the sides of bridges which have to endure violent gales. These plates both protect people and traffic crossing the bridge and deflect the force of the blast as it strikes the bridge.

From time to time, bridges collapse. Perhaps the most famous failure was that of the Tacoma Narrows suspension bridge built across the Puget Sound in Washington State, USA, in 1940. Just six months after completion, the deck began undulating ever more severely in a light gale and

Arches are strong structures because the weight at the top is deflected down the sides. This compresses the materials in the sides, making them stronger.



crashed into the water in one hour.

Most bridge accidents happen during construction, however, such as the collapse in August 1988 of a concrete beam bridge in Aschaffenburg, West Germany. Seven people were injured; one was killed.

Cutting tunnels

If bridges are the way to cross over natural or man-made obstructions, tunnels are the way to go underneath. The traditional method of making a tunnel is to bore one.

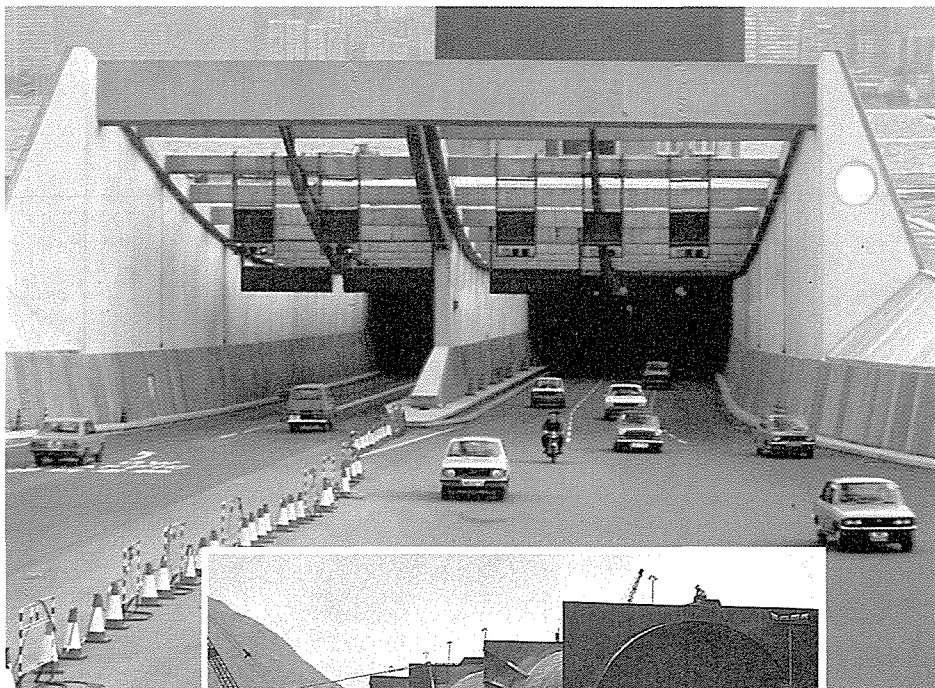
In soft ground, such as the chalk through which the Channel Tunnel was bored, a giant tunnel boring machine can be used. This resembles an enormous drill, which can be as long as 190 metres. The cutting head at the front is of the same diameter as the tunnel, and it is forced along the tunnel by hydraulic power. Behind the rotating cutting head is a series of conveyor belts. These take away the spoil to rail mounted wagons behind the machine that takes the waste above ground.

Behind the cutting head, the excavated tunnel is lined with segments of reinforced concrete or cast iron. The segments form a circle around the inside of the tunnel and, because the pressure bearing in on a circle is roughly equal from all sides, the lining prevents the walls or the ceiling from collapsing.

In hard ground, such as rock, tunnels are drilled and blasted through. Small holes are drilled at a short distance into the tunnel face and packed with explosive. When charges are fired, the drilled section crumbles and is cleared away. Then the process is repeated.

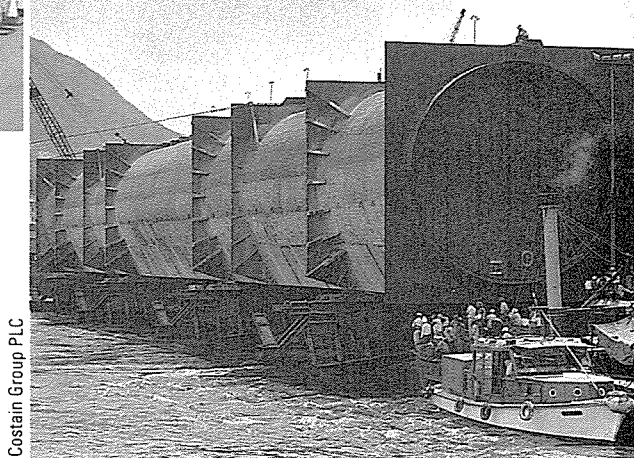
Tunnels through rock do not

Building the 'Chunnel'. Steel sheets are driven into the sea bed from jack-up barges to form a lagoon which will be filled up with tunnel spoil.



George Wimpey PLC

Tunnels join Hong Kong to the Chinese mainland. The new Hong Kong-Kowloon tunnel will probably be the biggest in the world. Gigantic precast tunnel units (right) are lowered gently beneath steel pontoons anchored to the sea bed.



Costain Group PLC

usually need linings — the rock forms its own load-bearing arch. However, if the rock contains many faults, it may need lining.

Unstable rock

Sometimes rock conditions are so bad that the rock ahead has to be stabilized before it can be blasted. The Japanese had to do this on the Seikan Tunnel. To make the rock secure enough to drill and blast — without causing uncontrolled collapses — the tunnellers had to drill holes in a fan shape outwards about 100 metres in front of them, then inject a cement grout into them. When the grout hardened, it made the rock tough and stable enough to tunnel through.

For tunnels under water, submerged tubes can be an alternative to a bored or blasted tunnel. This type of tunnel is made up of giant prefabricated sections, which are floated into position and sunk to the sea bed. They are then joined together and the joints are sealed.

The tunnel sections are usually lowered into a previously excavated trench on the bottom, which gives the completed tunnel a degree of extra protection. However, as in the case of the Hong Kong-Kowloon tunnel, the trench bottom is not even enough to lay the sections on, so an even bed of sand must first be

laid down. Once the tube is laid in the trench, it is usually covered over.

There is also an option for shallow land tunnels: the 'cut and cover' tunnel. Provided there is not too much rock or other strata on top, it can be more economical to make an open cut through the obstacle, then cover it with steel or concrete beams.

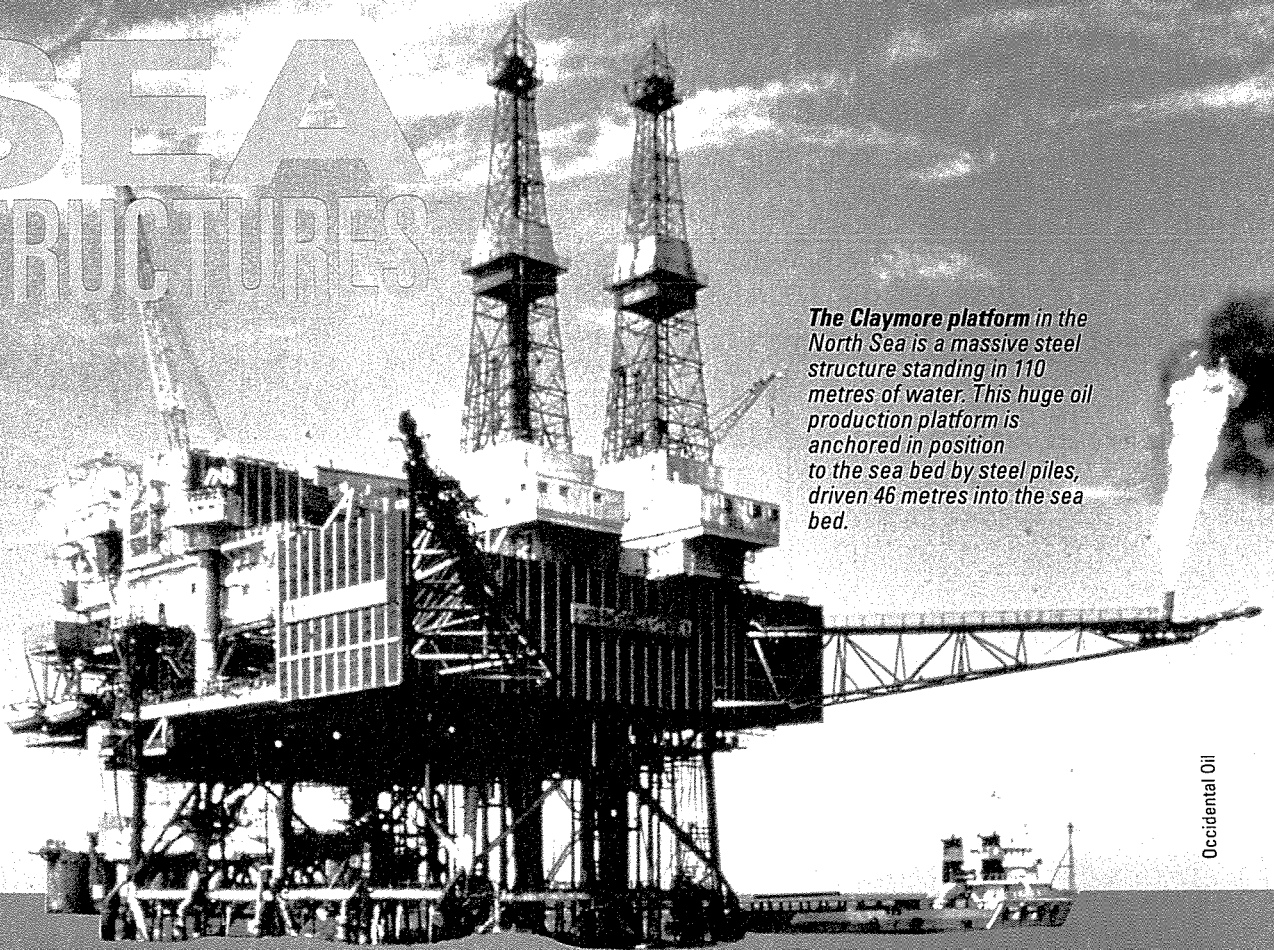


Paul Raymond

Costain Group PLC



SEA STRUCTURES



The Claymore platform in the North Sea is a massive steel structure standing in 110 metres of water. This huge oil production platform is anchored in position to the sea bed by steel piles, driven 46 metres into the sea bed.

Occidental Oil

CONSTRUCTING RIGS

SUPER CRANES

ARTIFICIAL ISLANDS

BUILDING HUGE STRUCTURES on water developed through the need to extract oil and gas from fields that lie under the ocean.

Altogether there are now more than 1,500 oil platforms stationed in the oceans of the world. The North Sea and the Gulf of Mexico are the two offshore areas that have seen the most development.

There are two main types of permanent offshore platform. In most cases, the oil men live and work on a steel structure that contains the drilling rigs and processing equipment as well as sleeping quarters, cinemas and restaurants. It is the supporting structures that vary. One type consists of lattice steel supports, which stand on the sea bed on four or more legs. Other rigs have concrete bases, which are floated into position and then sunk.

Floating structures

As well as these platforms, which are all fixed to the sea bed, the offshore oil and gas industry has spawned various floating structures. The most impressive of these

are crane barges, which can lift up to 14,000 tonnes.

Steel supporting structures, called jackets, once had to be floated out to sea on barges and up-ended when they reached their destination. However, the huge cranes now available can lift most jackets into place from the deck of the barge. Steel piles – giant pipes – are then driven through the base of the jackets deep into the sea bed to anchor them in place.

The discovery of oil and gas in the North Sea led to existing technology being taken to undreamed-of dimensions. For instance, the cylindrical steel piles used to nail the four steel platforms in the Forties oil field (in the North Sea) to the sea bed were 1.37 metres in diameter and 270 metres long – nearly twice the height of the British Telecom Tower in London. Each platform needed 36 of them. Once the jacket has been fixed in position, the decks are placed on top, either in one piece or in separate modules.

Concrete towers

The concrete structures used to support some oil platforms are the heaviest floating structures man has ever devised. One now being built in Norway will weigh more than one million tonnes. How do such immensely heavy objects float?

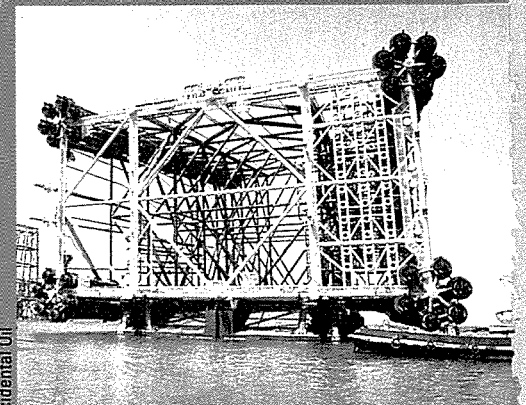
The answer is that they have

giant buoyancy tanks built into them. These hold enough air to make the structure float and, by emptying and refilling the tanks, the jacket can be made to rise and fall in the water.

The deck is floated out on a barge to a point in deep water to be mated with the jacket. The jacket is lowered in the water so that the barge can float over it. Then the jacket is raised to lift the deck off the barge.

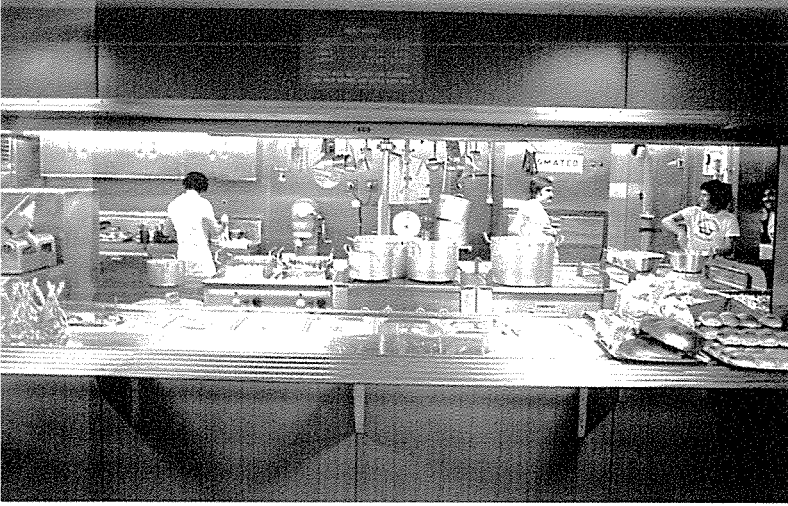
Once a survey and test drilling have shown that it should be economic to build a permanent rig on a

The steel jacket of an oil platform, ready to be eased on to a barge for towing out to its destination in the North Sea.



Occidental Oil





Occidental Oil

site, planning and construction can begin. A typical modern rig takes at least two years to build. The development of all this technology has encouraged people to look at building other massive structures on water.

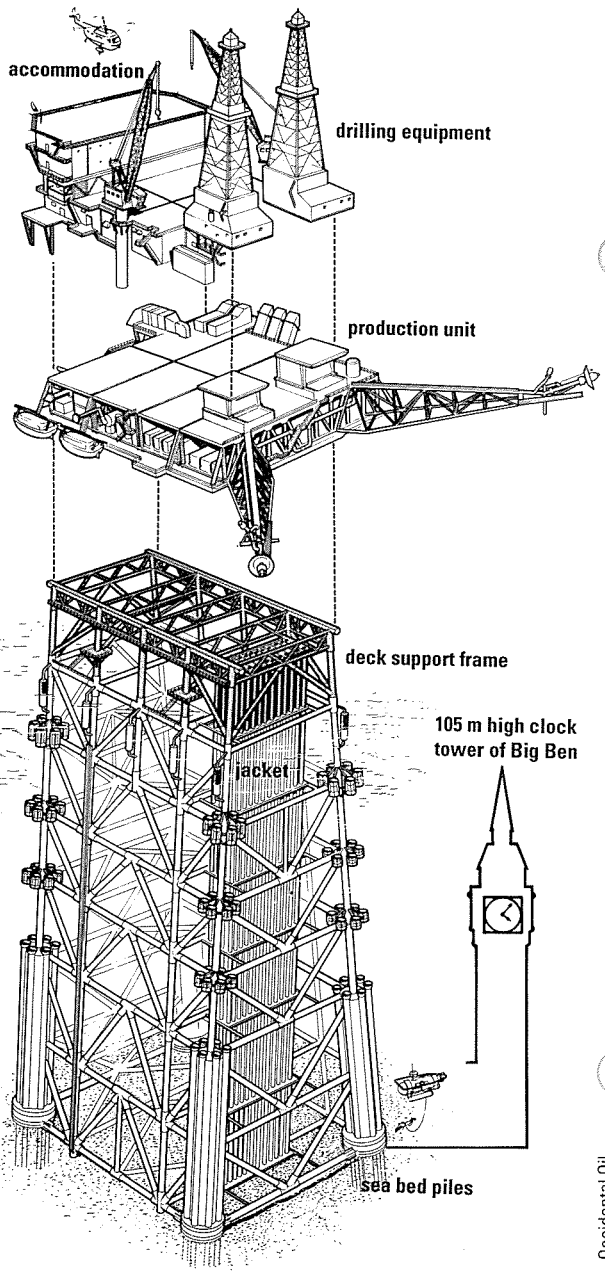
Power station

Italian engineers are working on plans to build a floating power station off their western coast. A similar scheme (with a difference) is being proposed in the Philippines — a small floating power station that would be able to sail around the islands and plug into areas that were facing temporary shortages of electricity.

Of course the cost of building on water will always be higher than that of building on land, so offshore construction is likely to happen only where there are pressing environmental reasons for remote locations, as in the case where overcrowding on land forces man to build new cities on artificial islands in the sea.

High-quality food is prepared in a well-equipped kitchen on the rig. Each week, the rig workers consume about 70 kg butter, 320 kg flour, 450 kg fruit, 2,540 litres milk, 900 kg meat and 450 kg vegetables.

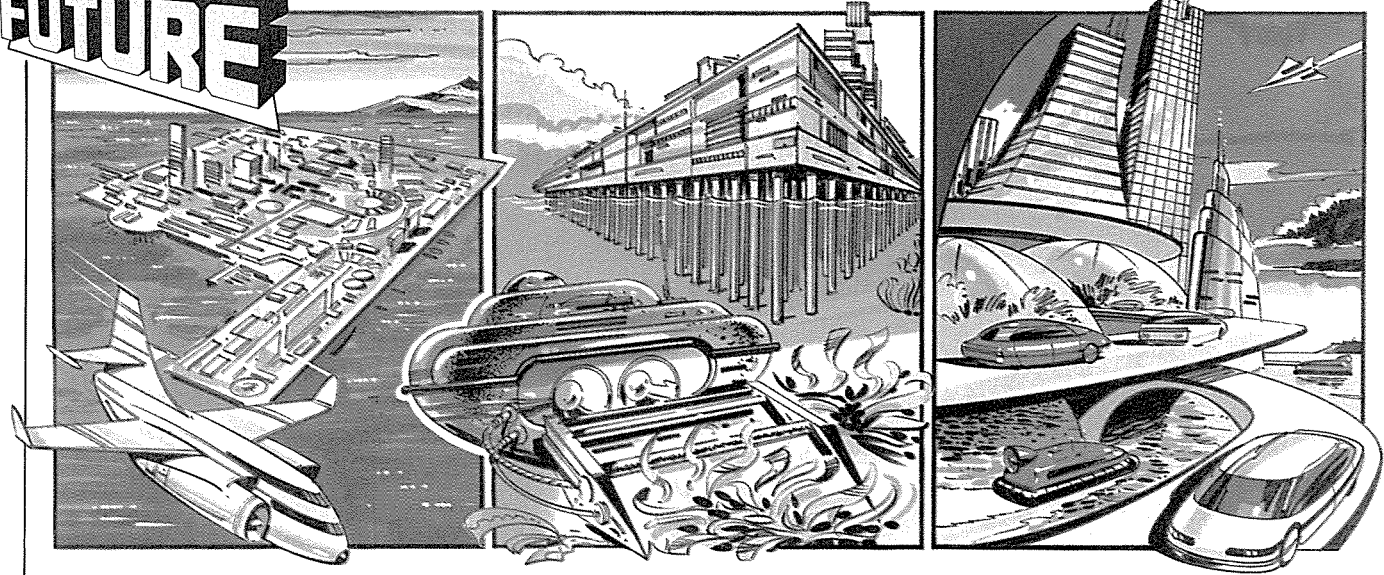
The structure of the Claymore oil production platform, clearly revealed. The steel jacket, rising 152 metres from the sea bed would dwarf the 105 metre Big Ben clock tower (in London). The deck support frame evenly distributes the weight of the upper modules to the jacket and the sea bed.



Occidental Oil

INTO THE FUTURE

AN OCEAN CITY



Joe Lawrence

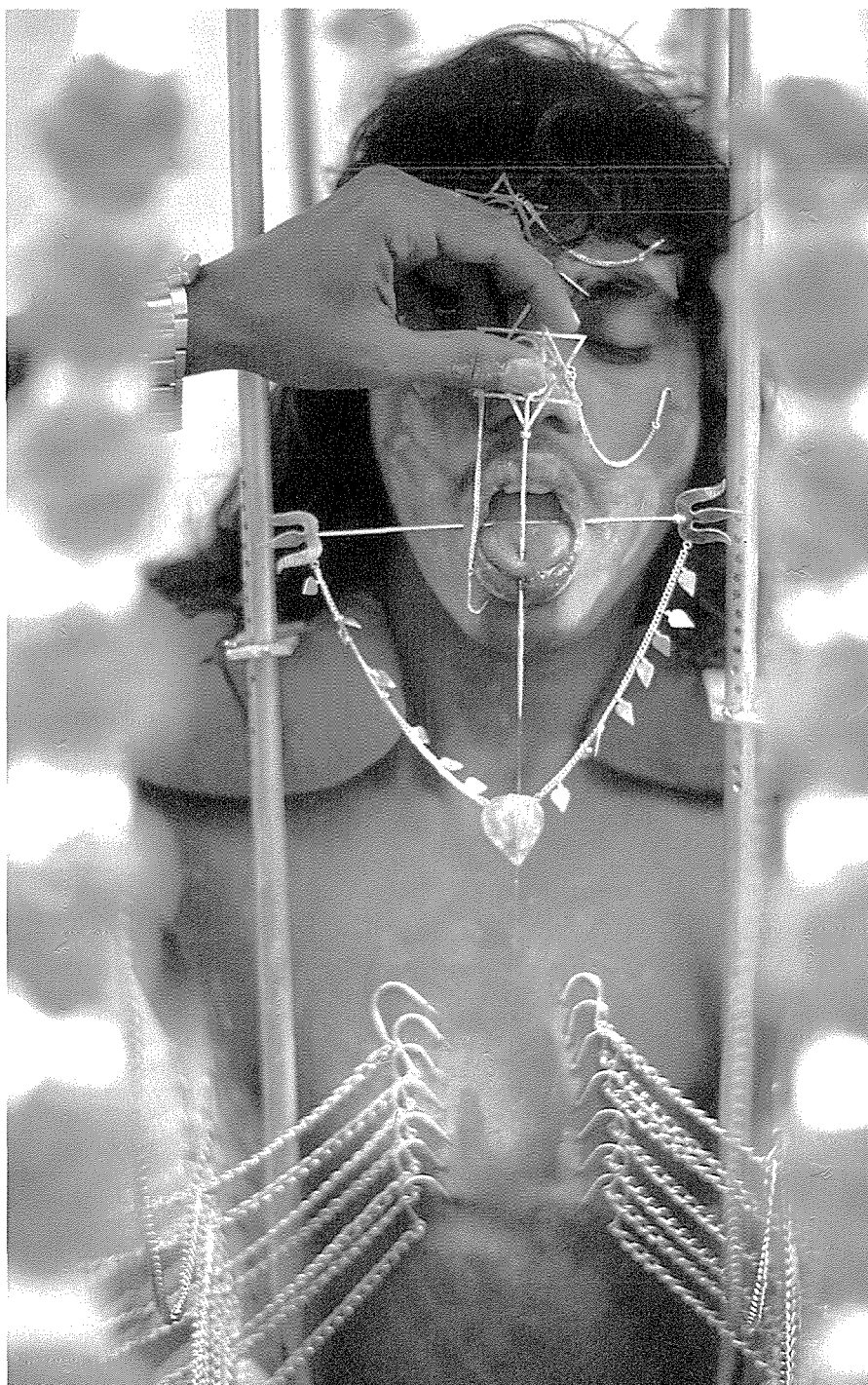
▲ The Ocean Communications City, an artificial island in the Pacific 120 km from Tokyo, will be home and workplace for up to one million Japanese.

▲ Ten thousand shock-absorbing columns will support the 23 km² structure. Underwater farms may provide the inhabitants with fruit and vegetables.

▲ Access to this \$200 billion sea city will be by plane and hovercraft. Electric cars will provide transport around the island on perfectly smooth roads.

MIND

OVER MATTER



Scot Sothorn/Black Star/Colorific!

The power of the mind to withstand pain is amazing. A Hindu mystic can turn into a human pin cushion without bleeding because he has learnt to control parts of his mind through special training. Similarly, a man trained to walk barefoot over burning coals (inset above) incurs no injury to his feet.

Faith can heal – but it is not known how. Sick and disabled pilgrims visit Lourdes in France, the site of a miracle, hoping to be cured.

Tony Stone Photolibrary London

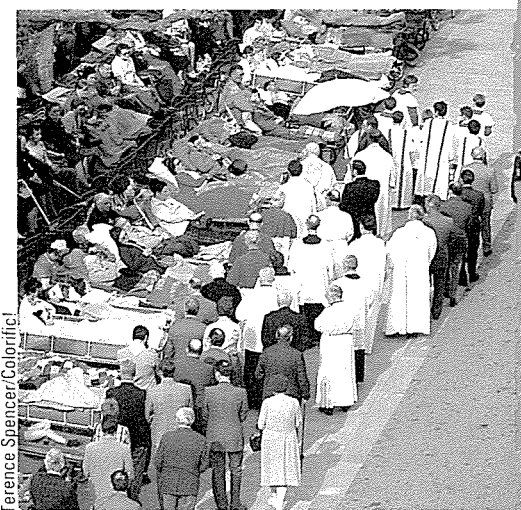
- ESP
- BEING THERE
- ALTERED STATES

SPOON BENDING, READING minds, communicating with the dead – these are some of the instances of the paranormal.

While neurology can explain much that occurs in the brain and the mind, there are many events that cannot be explained using current knowledge. Such events are usually classified as paranormal or extra-sensory perception – ESP.

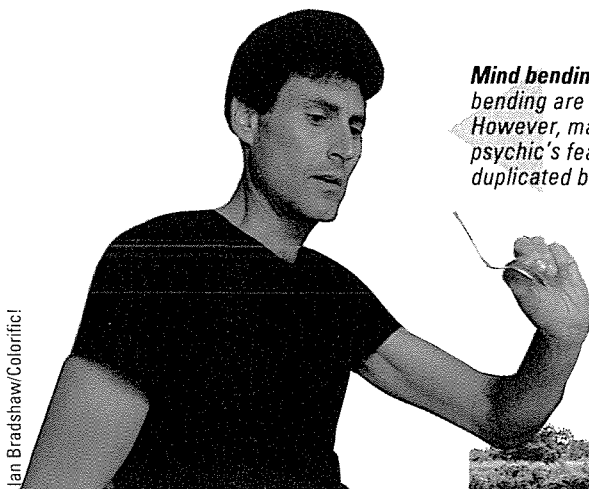
Among the many instances of the paranormal are:

- telepathy, which is defined as the transmission of information from one mind to another without using any of the normal methods available to human beings, such as language, movement or signs
- clairvoyance, which involves acquiring information that is not known to any other mind – its practitioners argue that the information they receive comes from the spiritual world
- precognition: acquiring information about an event before it takes place, which invariably takes the form of a dream about, say, a disaster occurring
- psycho-kinesis, the ability to manipulate matter or to move



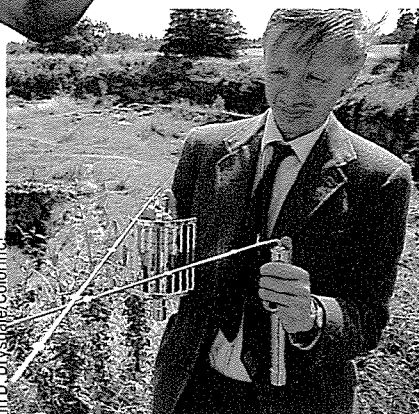
Terence Spencer/Colorific!





Mind bending feats such as spoon bending are Uri Geller's speciality. However, many of this famous psychic's feats have been duplicated by conjurors.

A dowser or diviner can find water or mineral with (or without) the help of special rods. This particular talent may have something to do with radiation.



John D. Drysdale/Colorific!

objects from a distance without employing known physical means.

Although paranormal events are widely reported — and there is a great deal of anecdotal evidence, to date — not one repeatable paranormal effect has been discovered or been demonstrated in a controlled, scientific setting.

In controlled studies, persons with reported psychic powers have been unable to harness them in the laboratory. There is also rather damning evidence that shows some laboratory experiments, which apparently proved an individual's psychic powers, were actually fixed or manipulated.

Hidden powers

However, paranormal events that have been observed often cannot be explained. Some scientists believe that we may be in possession of certain powers that we are not conscious of. Or that we may even have a communication system that works in the manner of radio

waves, which we do not know about, or are largely unable to harness. Until research shows otherwise, however, the existence of the paranormal is doubted by most scientists.

An event that nearly everyone is familiar with is that of having already been in a situation, or of having seen something before in another time. Those of certain religious or spiritual persuasions argue that this situation, known as *dejà vu* (French for 'already seen'), is proof of humans living previous lives in other bodies or forms.

More plausible explanations do exist, however. Some would argue that we may have dreamed of the event or situation so vividly that when we find ourselves in that situation it seems all too familiar, since we have 'been there' in our dreams.

Then again, a situation may contain many events and surroundings that we have seen or experienced before, so that we may feel we have been in the situation previously.

One theory of *dejà vu* involves memory. Some argue that a memory of what we choose to store is laid down in the mind, rather than what actually happened. So, although we may have been somewhere that was vaguely similar, the memory of that place has been modified till it is now identical to the situation we are experiencing.

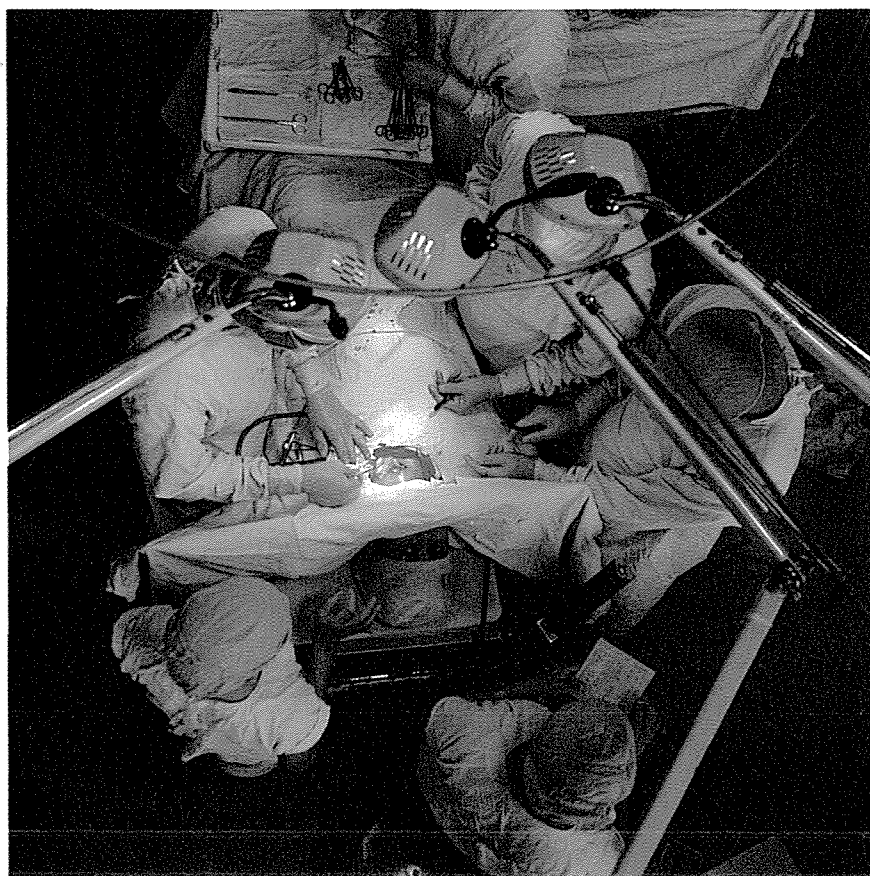
Hypnotism

Hypnotized subjects are often described as being in a state of 'waking consciousness'. They are highly susceptible to the hypnotist's suggestions and will quite readily take on any role they may be asked to.

While it is easy to hypnotize certain people, it is not quite clear what is happening to them physiologically. So the hypnotic trance is widely regarded as a psychological phenomenon.

Certain people cannot be hypnotized. The most susceptible to hypnosis are children between the ages of eight and 12, who seem to be better at dissociating certain mental capacities from normal consciousness. Hypnotism is used widely in medicine and dentistry and for control of pain and some forms of psychotherapy.

Wide awake under the knife, thanks to acupuncture. Needles are used to anaesthetize a patient during thyroid surgery.

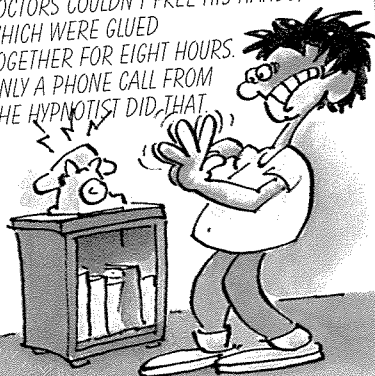


Sally & Richard Greenhill

Just amazing!

GET THAT PHONE!

AFTER WATCHING A HYPNOTIST ON TV, AN ITALIAN BOY FELL INTO A TRANCE. DOCTORS COULDN'T FREE HIS HANDS, WHICH WERE GLUED TOGETHER FOR EIGHT HOURS. ONLY A PHONE CALL FROM THE HYPNOTIST DID THAT.



Paul Raymond

■ ALLUVIAL GOLD

■ RE-CYCLED SILVER

■ MOND PROCESS

THE EARTH'S RICHES

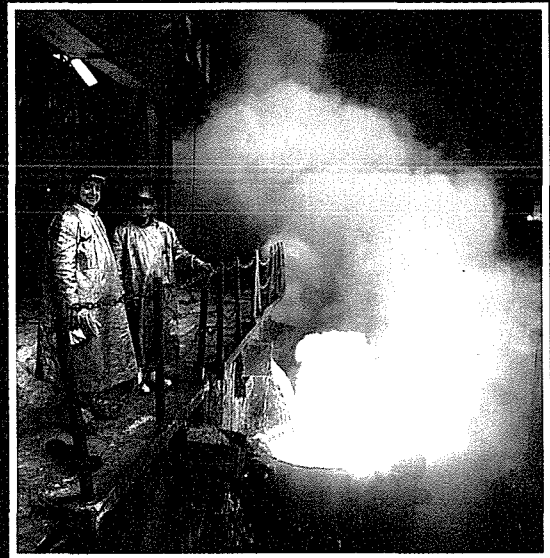
A ROYAL CROWN, A GOLD-plated mascot on the front of a Rolls Royce, ingots stacked in the vaults of a bank — wherever it crops up, gold symbolizes wealth and power because of the huge effort required to find it and extract it from the earth.

Gold is one of the most highly prized of all metals and, for this reason, it has always been used to mint coins. Gold also gives value to paper notes — in theory, these can be swapped for gold.

Unlike most metals, gold does not react with other common elements such as oxygen, sulphur or carbon. This is why it is known as a 'noble' metal. For the same reason, gold is found in nature as a pure metal rather than as a compound.

Most particles or nuggets are found in veins of quartz deep within hard, crystalline rocks, such as granite.

Copper is extracted by roasting the ore in a furnace. The work is dangerous, so the men wear heat-resisting coats when the molten metal is cast into ingots.



ZIFA

nite and solid quartz rock. They are also found in deposits of sand and silt washed out of quartz veins by running water. This is known as alluvial gold and is often found along the beds of streams and rivers.

● Hard rock mining

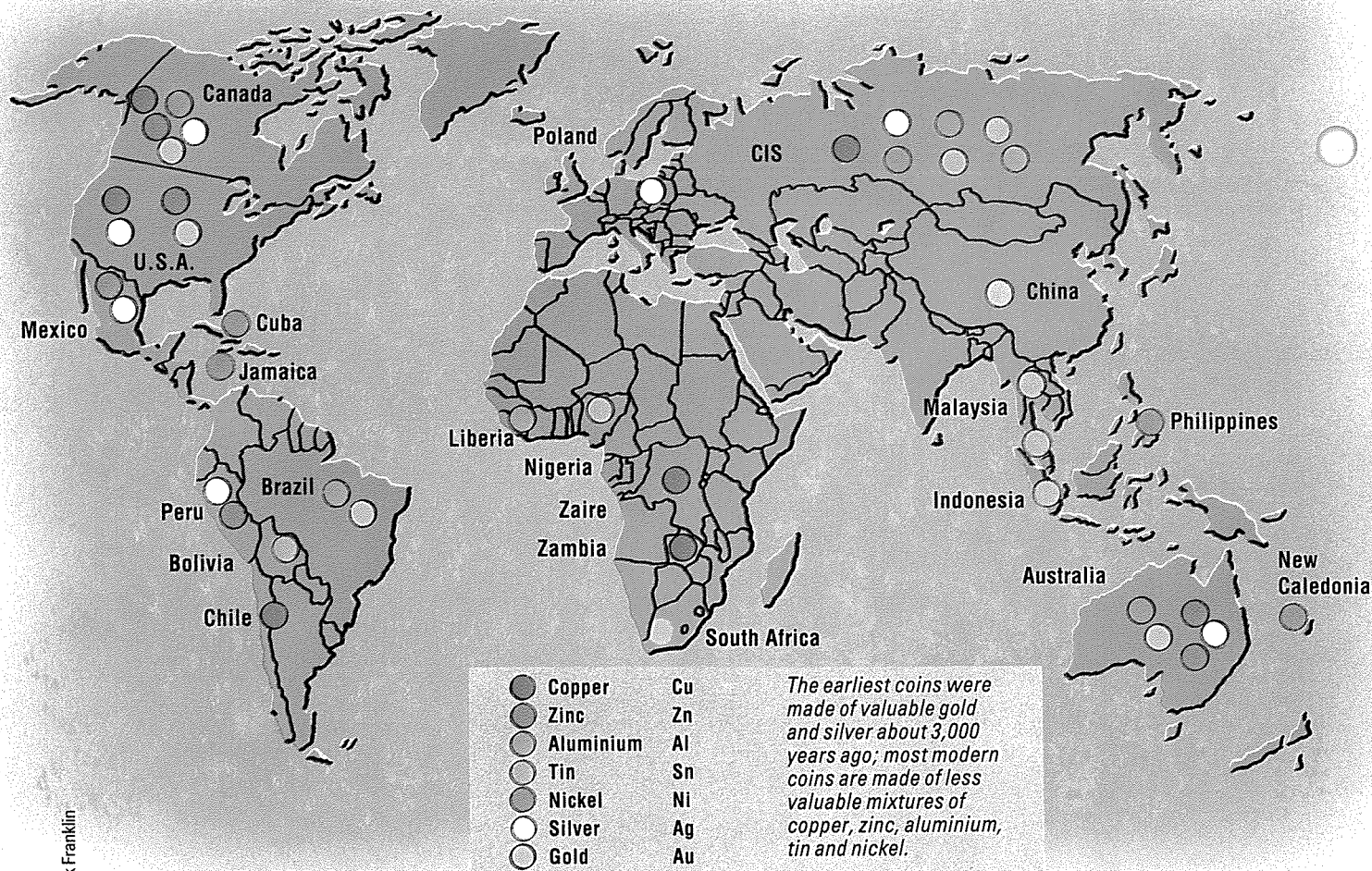
Gold is found in lots of places around the world, but only a few countries have enough to support a gold mining industry (see map overleaf). The gold-bearing rock is usually extracted by underground mining in hard rock, often at great depths. Thus the Western Deep Levels mine

at Carletonville, South Africa, is the deepest mine in the world, extending 3,777 metres down. At the lowest level of the mine, the temperature is 55°C.

Alluvial gold is extracted by dredging gold-bearing silt from the bottoms of lakes, or by using high pressure water jets to wash deposits out of the sides of hills. In some countries — Brazil, for instance — individual prospectors and

Miners start work by drilling deep holes in the rock that contains the ore they want. Explosive charges are placed in the holes and everybody is cleared out of the mine before they are fired. The rock is broken into pieces, ready for loading.





Mark Franklin

miners extract alluvial gold by washing and sieving gravel from the beds of rivers by hand. Gold miners in the old Wild West used this method of mining.

Today, gold is only used as everyday currency in remote parts of Arabia, where normal coins are unknown. Special golden guineas are minted by the Bank of England and

PURE GOLD

Pure – 24 carat – gold is so soft that it is not even strong enough for making jewellery. To give it more strength, gold is nearly always mixed with other metals like copper. For example, American golden dollars contain 10 per cent copper.

The purity of gold is normally measured in carats. If a ring were made of nine carat gold, nine parts out of 24 would be pure gold. The purest gold normally used for making jewellery is 22 carat, which is 22 parts pure gold out of 24.

Besides ornamentation, gold has many industrial uses. In fact, 10–15 per cent of world gold production is used in this way. One of the commonest uses is in electrical switches – the contacts that conduct the electricity are often plated with gold. This prevents wear due to sparking because gold is too soft to make sparks.

Seven metals are used for making coins. Ores from mines are usually processed in Western Europe or America to extract the metals.

exported directly to these areas. Large quantities of other gold coins, including the Kruggerrand from South Africa and the Maria Theresa thaler from Austria, are still minted for people who want to buy gold as an investment instead of, say, shares.

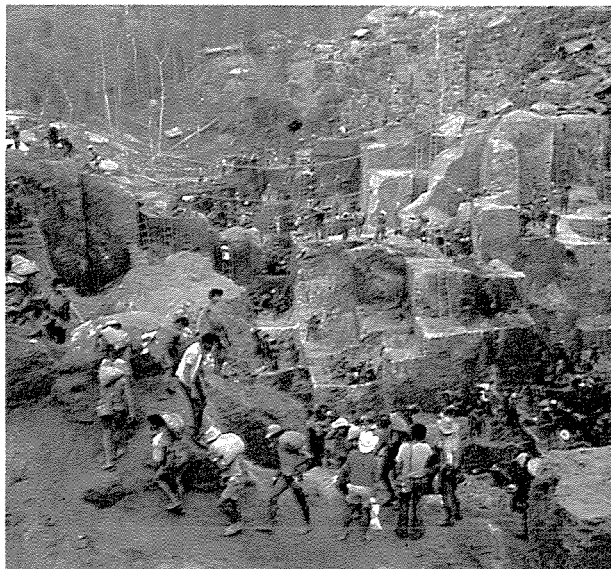
Silver is the only precious metal still used in ordinary coins but even this practice is restricted to a few rich countries, notably Germany and Switzerland. Most silver is now

obtained as a byproduct during the production of other, cheaper metals, such as copper, zinc and nickel. The ores of these metals contain small amounts of silver, so when electrolysis is used during copper or nickel refining, silver settles into the sludge of impurities that settle at the bottom of the tank. This sludge can then be further refined to recover the silver.

Chemical extraction

Like gold, silver may be found in its native state, but Argentite silver ore is mined in a few places (see map above). The ore is first dissolved in a sodium cyanide solution, which produces a compound called

Illegal gold miners in Brazil work in terrible conditions to extract the bright metal. At Serra Pelada, they have dug the largest open cast gold mine in the world and they lift the gold-bearing rock to the surface on their shoulders. Elsewhere in Brazil, they use mercury to extract gold from river beds. This releases the poisonous metal into the river, killing miners and fish.



Zefa



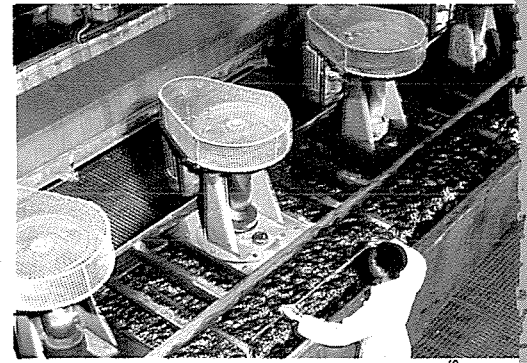


Hard rock miners use pneumatic drills – similar to ordinary road drills – to bore the rock for the explosives.

To separate metal ore from valueless rock, it is immersed in water. The ore rises to the surface and is skimmed off.

Hundreds of tonnes of silver ore are crushed in revolving steel drums. Lumps of ore are flung against the sides by centrifugal force. The noise is ear-splitting!

Anglo American Corporation



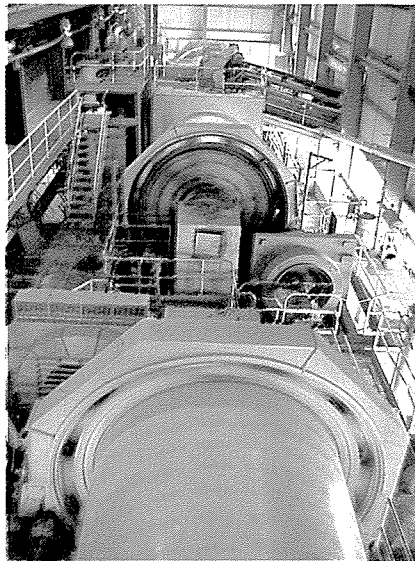
Cambridge School of Mines

sodium argentocyanide. Zinc dust is added to this solution and the zinc combines with the sodium and cyanide because they are more reactive than the silver. This frees the silver from the compound and it sinks to the bottom of the tank.

A similar cyanide process is used to recover gold when the particles are too fine to be separated from silt or crushed rock by simply sifting or washing the unwanted material away.

Lots of silver is used industrially, particularly for photography and for making printing plates. When the films and plates are developed, a lot of silver is removed as waste. The waste is then passed through an electrical device that recovers the silver electrolytically. Silver recycled in this way is an important source of 'new' silver.

Most modern coins are made from the cheaper, more plentiful metals such as copper and tin – the 'base metals'. Among these, pure



David Leah/Science Photo Library

copper is occasionally found inside rocks and is known as 'native' copper. More commonly, it is found in ores in the form of copper sulphide (copper combined with sulphur) or, less often, copper oxide (copper combined with oxygen).

Rock containing the copper ore is obtained from opencast mines, which are like huge quarries, or dug out of mines. The ore-bearing rock is crushed in a ball mill by heavy rollers, each 6 metres in diameter, 7 metres wide and driven by a 5,000 horse power electric motor. After crushing, the copper ore is separated from the rest of the rock, at which point it is known as a concentrate.

Electrolytic copper

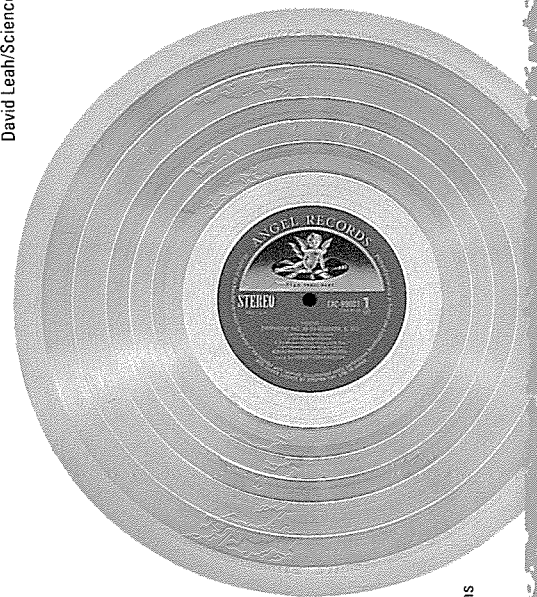
Copper sulphide ore is simply melted in a furnace to separate the sulphur from the copper. Oxide ore is dissolved in a tank of sulphuric acid, then the copper is extracted by electrolysis. Two copper rods (called electrodes) are lowered into the acid and an electric current is passed through the acid from one

electrode to the other. Pure copper builds up on the negative electrode. Any impurities end up as a slimy sludge on the bottom of the tank. When the process is finished, the electrodes are lifted out of the acid, melted and then cast into ingots. Copper extracted in this way is known as electrolytic copper and is very pure.

The most important zinc ore is zinc sulphide. Crushed zinc ore is heated in a furnace to convert the zinc sulphide into zinc oxide. Then the oxide is heated with carbon to remove the oxygen and produce pure zinc. The oxygen and carbon combine to form carbon dioxide gas, which floats away, leaving the pure metal.

The main nickel ore is nickel sulphide. As with zinc production, the first stage in producing nickel

SOLID GOLD SOUNDS



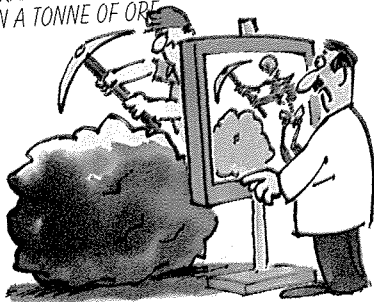
Ray Duns

Gold and silver records are normal vinyl discs with a thin coating of metal on the surface. For gold records, 24 carat gold is used; 'silver' records are coated with aluminium. A genuine copy of the hit record is placed in a vacuum chamber and given a negative charge of electricity. The metal is then vaporized and positive metal ions are attracted to the record's negative surface.

Just amazing!

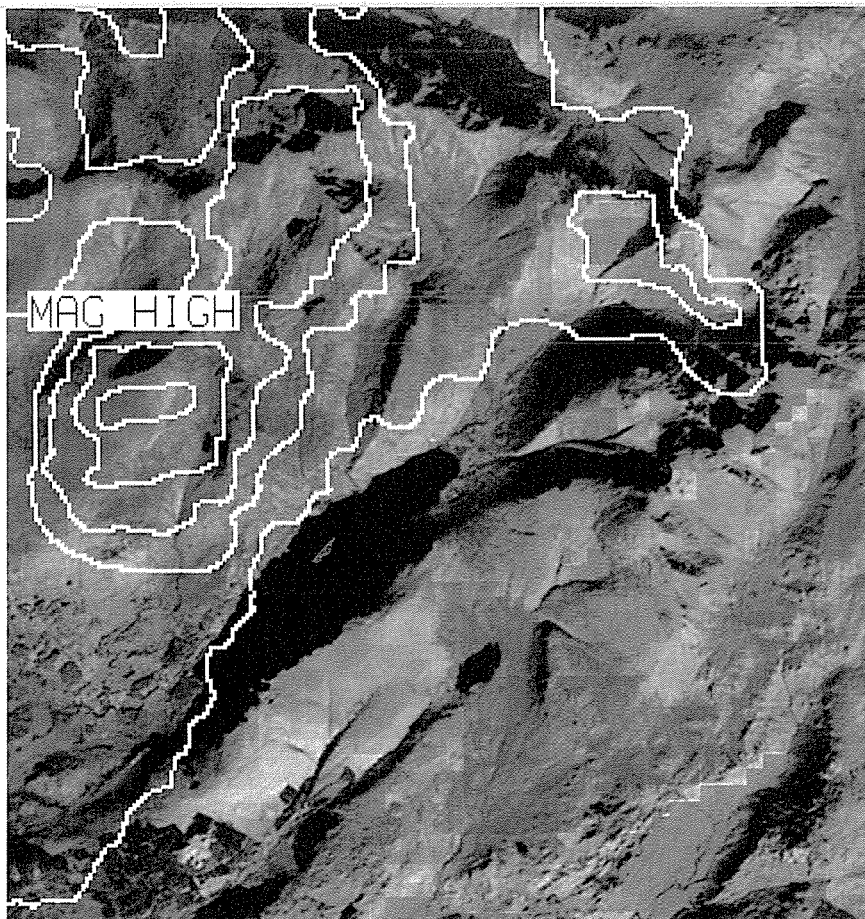
GOING FOR GOLD

A NEW X-RAY MACHINE CAN DETECT MINUTE AMOUNTS OF GOLD IN A SAMPLE OF ORE. USING HIGH SPEED ELECTRONIC CIRCUITS, IT CAN TRACE AS LITTLE AS 0.2 GRAMS (EQUIVALENT TO 20 GRAINS OF RICE) IN A TONNE OF ORE.



Paul Raymonde



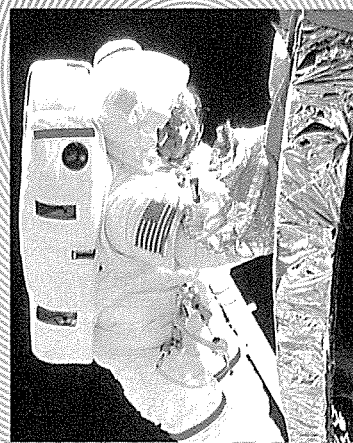


The nickel carbonyl is then heated to about 180°C . At that temperature it gives off carbon monoxide, leaving little pellets of pure nickel.

A lot of tin is found as a pure metal but the main ore is cassiterite (tin oxide). This is found inside rocks, but some of the most important deposits occur in beds of sand and gravel. The ore is converted into tin by heating it in a furnace with anthracite — a hard coal containing a very high percentage of carbon.

A UNIQUE METAL

Gold is very malleable, which means that it can easily be worked into all sorts of shapes. It can even be beaten out so thin that it becomes transparent. This cannot be done with any other metal. Sheets of this transparent gold are built into the windscreen of Concorde and into the visors of astronauts. A small electric current is passed through the gold, which heats up gently and so prevents the glass misting up.



NRSC Farnborough

NASA/Science Photo Library

from the mined ore is to heat it in a furnace to convert the nickel sulphide into nickel oxide.

A mixture of hydrogen and carbon monoxide gas, known as producer gas, is then pumped into the furnace. This combines with the oxygen, leaving an impure nickel.

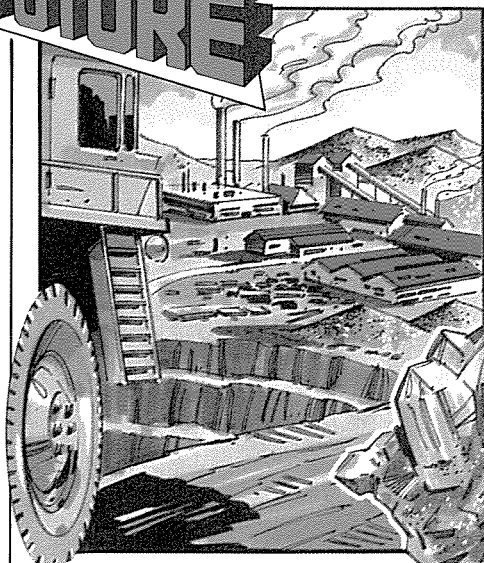
In North America, the nickel is usually refined by electrolysis (similar to the process used for copper oxide), elsewhere the Mond process is generally used.

Satellite pictures, enhanced by computer, can help to locate deposits of metal ore from the magnetic characteristics of the rocks. Here, tin ore is orange.

The Mond process consists of a two-stage operation. First, the nickel is heated with producer gas, but this time to only 50°C , which is a much lower temperature than before. This produces a compound called nickel carbonyl, which consists of nickel, carbon and oxygen.

INTO THE FUTURE

GOLD BUGS



▲ With conventional processing, a staggering 90 per cent of gold is still left in the ore. The gold is trapped in pyrites (iron sulphides).



▲ Because methods of extracting this trapped gold cause severe pollution, scientists are developing a unique group of microbes capable of digesting the pyrites.



▲ In doing so, the microbes will expose almost all the gold previously trapped in the sulphide. The gold can then be extracted with cyanide in the usual way.

Jane Lawrence



INTO THE UNKNOWN

Q JUNGLE LORE

Q THE DANGERS WITHIN

Q INTO THE CANOPY

THE MYSTERIES, DANGERS and riches of the jungle have proved an irresistible challenge to explorers, mainly from Europe, for hundreds of years.

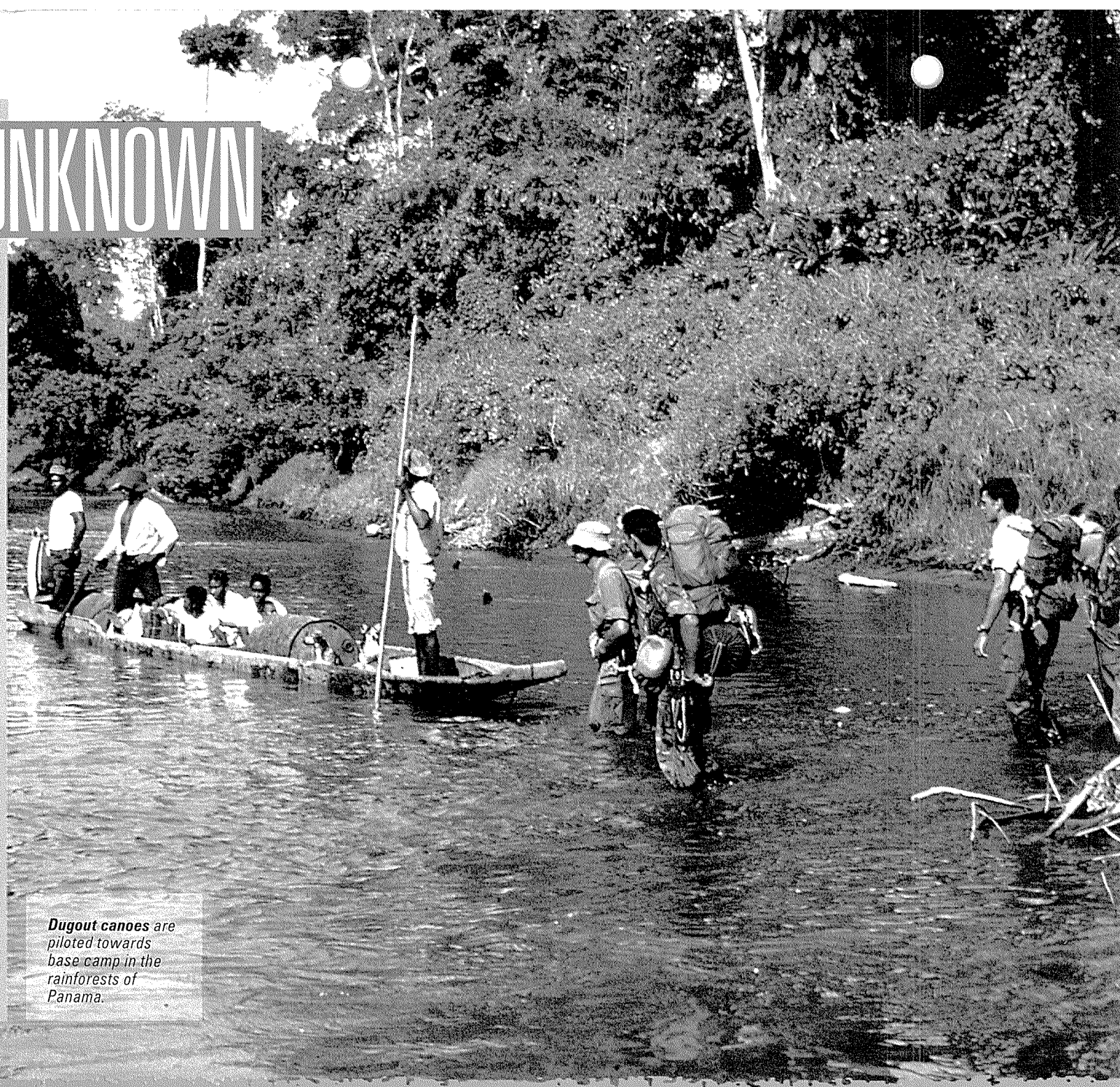
Although 20th-century jungle explorers can take advantage of modern technology, they still have to overcome the tremendous problems caused by heat, humidity and slow communications deep in the jungle. On many days, cooking, purifying water, driving vehicles along muddy tracks and just surviving, make it impossible to carry out scientific or filming work. Everything seems to take twice as long and be three times more difficult than normal, not to mention the near-certainty of illness.

Filming the forest

Phil Agland, maker of the 1982 award-winning film *Korup: an African Rainforest*, spent thousands of hours perched uncomfortably on platforms high in the forest canopy, filming the wildlife around him. It took six and a half weeks to capture on film white-nosed monkeys pollinating the *Pentadesma* tree.

The problems of filming in a rain forest are formidable. To begin with great patience is needed. Agland

Dugout canoes are piloted towards base camp in the rainforests of Panama.



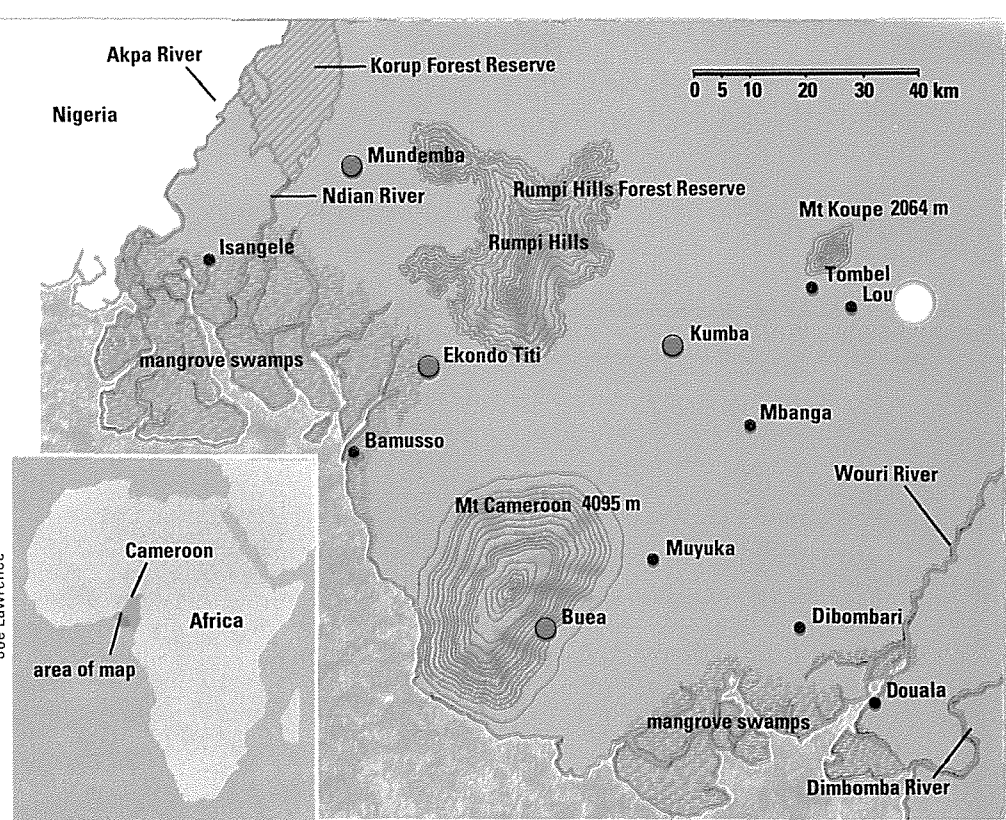
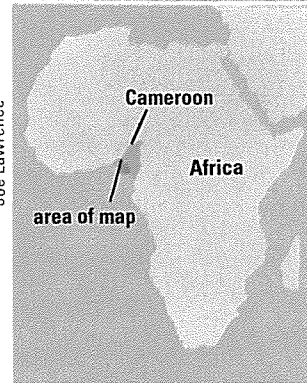
found fungus growing in his camera and the humidity ruined his unused film. In the end, however, the programmes he made were superb and became the centre of a campaign to save the rain forests.

In the jungle, film crews are often forced to eat unusual foods if their own supplies run out. On a wild boar hunt through a rain forest with the Maku people, the *Disappearing World* team from Granada Television, Manchester, England, had to eat fried flying ants for three days – apparently they tasted like bacon fried in butter. More familiar delicacies, such as rice, corn and various fruits may well be available, but a local guide is essential to tell you which foods are safe to eat.

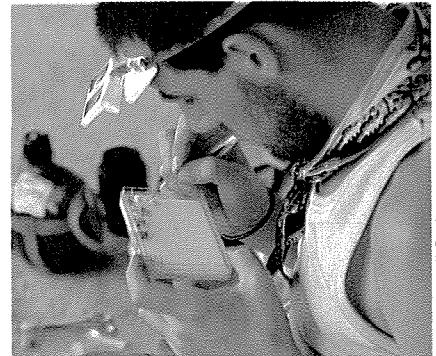
Today's explorers know that the

The area of an expedition by the UK based Operation Raleigh team to the Cameroon, close to the Nigerian border in 1989. The team had various objectives, including zoological surveys.

Joe Lawrence



Christopher Sansbury/Orpix



J Wedderburn/Orpix

A moth survey in Cameroon for the Worldwide Fund for Nature discovered about 1,000 species, 150 of which were new.

A camera crew from London, England, working in Belize, Central America, on a film about the diverse life on a fig tree.

The Rio Claro suspension bridge, on the Osa Peninsula near Drake Bay in Costa Rica, is 30 metres in length.

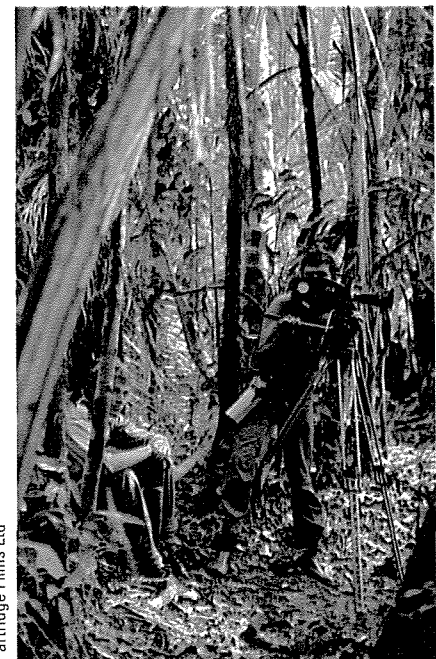
Bridge building in Costa Rica in 1985 – part of a programme to help villagers across the River Claro in the wet season.

interior of the rain forest is not an impenetrable tangle of greenery with dangerous animals lurking behind every tree. But dangers still exist. Slippery tracks, fallen logs and shallow tree roots that snake across the jungle floor are all potential hazards.

Even leaning against a tree can be hazardous – animals may be disturbed or the tree itself may present hidden dangers. The sandbox tree, for example, has nasty spikes growing out of its trunk, sap that can blind if it gets into the eyes and fruit that explodes and sends poisonous seeds flying up to 20 metres away.

Most larger animals, such as

R Fitzgerald/Orpix



Partridge Films Ltd





Solea base camp in *Seram, Indonesia*, was the centre of operations for an expedition that carried out a full rain forest survey of wildlife and plants in 1980.

simple harness of vines to obtain honey from high in the trees.

To climb into the canopy, Donald Perry, a biologist exploring the jungle canopy in Costa Rica, used mountaineering gear. This allowed him to slowly inch his way up into the thick, jungle roof. A crossbow fired ropes over high branches.



snakes, have to be treated with respect. Needless to say all modern expeditions carry snake-bite serum. Ticks have to be carefully removed at the end of each day, as do leeches. A lighted match or pinch of salt is usually enough to make a leech release its hold, but the wounds need to be treated, as a matter of course, with antiseptics and antibiotics. Wounds heal slowly in the hot, humid jungle climate and can easily get infected.

Many insects, such as mosquitos, carry diseases. But today's explorers can be immunized against diseases such as yellow fever and can take tablets to protect themselves against malaria. (Malaria tablets contain quinine, which was originally obtained from the bark of a rain forest tree.)

Slippery climb

Less dangerous insects, such as ants, can be kept out of sleeping bags by putting petroleum jelly on any ropes or strings they might climb in the night. An expedition to film the Waorani people of Amazonian Ecuador was plagued by small stingless 'sweatbees' that could only be shaken off for a few mi-

nutes by a dip in the river.

Tents are usually too hot and stuffy for jungles and it is inadvisable to sleep on the ground. The best solution seems to be a hammock with a mosquito net to give

The forest canopy offers great rewards but the dangers, as with this wildlife observation hide, are real. An aerial walkway (below) under construction in the jungles of Costa Rica.



Just amazing!

WATER, WATER...

THE AMAZON IS THE WORLD'S BIGGEST RIVER. IT POURS INTO THE ATLANTIC WITH SUCH FORCE THAT IT IS POSSIBLE TO SCOOP UP A CUP OF FRESH RIVER WATER 160 KM INTO THE SEA.

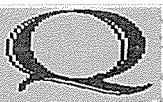


Primary health care programmes, such as this one in *Guyana* in 1988, are one of the many purposes of modern expeditions to the tropical rain forests of the world.

protection from moths, flying beetles and bats as well as mosquitos. A waterproof plastic sheet acts as a 'roof' - but if this has any folds where water can collect, you can be drenched in the middle of the night by an unexpected shower.

One of the most rewarding pursuits in the jungle is to climb to the canopy. It is dangerous, but such danger is an everyday occurrence for natives who climb using only a





TRIBAL RITES



Hutchison Library

The Mehinacu tribeswomen of the Amazon have their legs bound to bloat their calves as part of their initiation into the tribe.

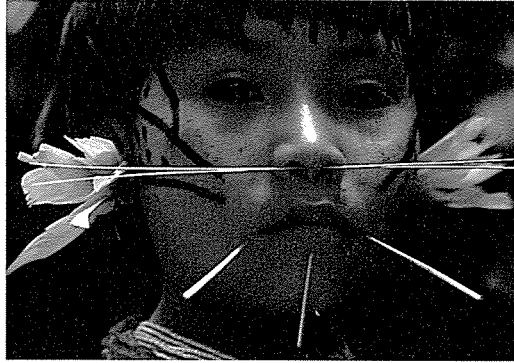
The annual feast of the Tanna people of Vanuatu begins with the ritual clubbing to death of the prized tribal pigs.



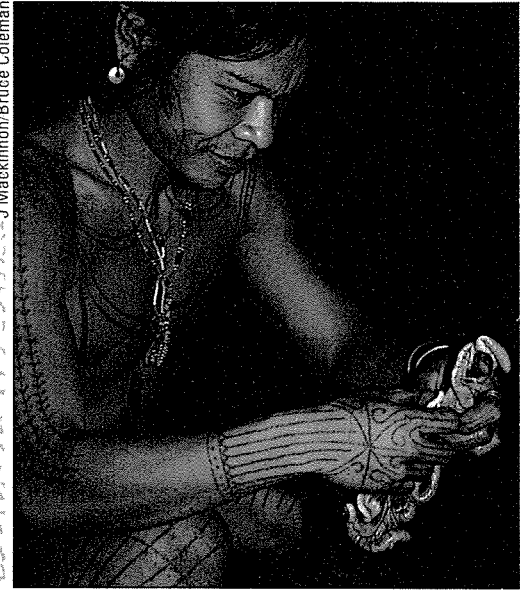
Karl
Susan Griggs Agency

Dressed up for a special occasion, a Yanomami Indian girl from Brazil wears the tribal equivalent of lipstick and mascara. The face painting represents animal spirits.

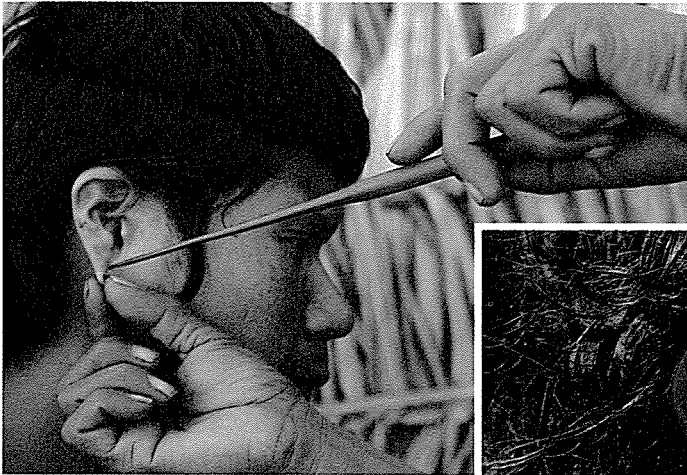
Victor Engelbert/Survival International



J. Mackinnon/Bruce Coleman Ltd



Animal intestines are the key to reading the future for a Siberut tribesman, native to Western Sumatra, in the East Indies.



L.C. Marigo/Bruce Coleman Ltd

The Kanela Indians of the Brazilian rain forests traditionally perforate their ears with sharpened sticks (above) and then fill the holes with a large, circular plug of wood for decorative purposes.

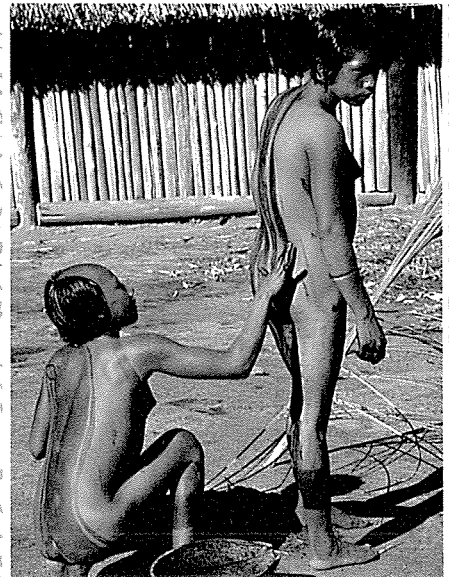


L.C. Marigo/Bruce Coleman Ltd

Tribal warriors of the Bawo Mataluo Indians of Nias, an island in Indonesia, perform a traditional warriors' dance.

Body paints are both decorative and symbolic for the Xingu Indian tribespeople of the Brazilian rain forest. The colourings are ground from plant or animal preparations.

Marcus Brooke/Colorfield



Robert Harding



THE GREENHOUSE EFFECT



RESPIRATION



THE WATER CYCLE



GLOBAL WARMING

RAIN FORESTS COVER around ten per cent of the world's land surface – roughly the area of Europe – but they are rich out of all proportion in wildlife.

They contain three-eighths of all the known species of land plants and one-third of the total weight of land plants and animals. The Amazon alone – the largest single area of jungle – is thought to be home to about half of all the plant and animal

P E Parker/Hutchison Library



If the jungles continue to be cut down at the same alarming rate, tropical rains (inset left) will cease and much of the Earth's surface could end up as desert. The rain forests' water cycle controls the global climate and helps maintain farmland.

Herald Sund/Image Bank

this process, oxygen is given off. All living things – both plants and animals – breathe in this oxygen.

Animals eat plants and so take in the nutrients produced in the plant by photosynthesis. Using the oxygen they breathe in, animals convert some of these nutrients to produce energy. As a by-product, carbon dioxide and water vapour are produced – both of which the animals breathe out. The remaining nutrients are used and excreted. The waste goes directly back into the soil and, when plants and animals die, they rot and thus provide nutrients for re-use.

Water and nutrients from the rain-soaked soil are sucked up through the roots of forest trees. The water, carrying the nutrients, passes up the trunk and stem into the leaves, and evaporates as water vapour. The water vapour rises into the air, condenses to form clouds, and falls again as rain.

Changing the weather

Normally, forest trees hold the soil between their roots, trapping the water and preventing erosion, which occurs when the jungle is felled.

In the Amazon the felling and

species in the entire world.

More than 30 billion tonnes of plant material grow in jungles annually – at 90 tonnes per hectare per year, this is twice as much as in a temperate forest in Europe or North America.

Essential cycles

Tropical rain forests are not only the richest places on Earth for plants and animals, they also affect global temperature, rainfall and weather patterns. Cutting them down could have – and perhaps is having – disastrous effects all over the world.

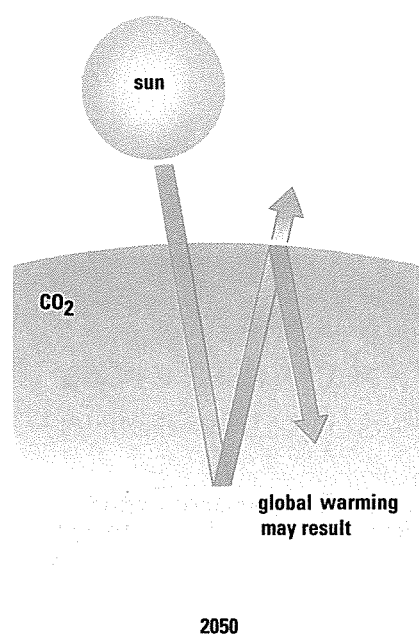
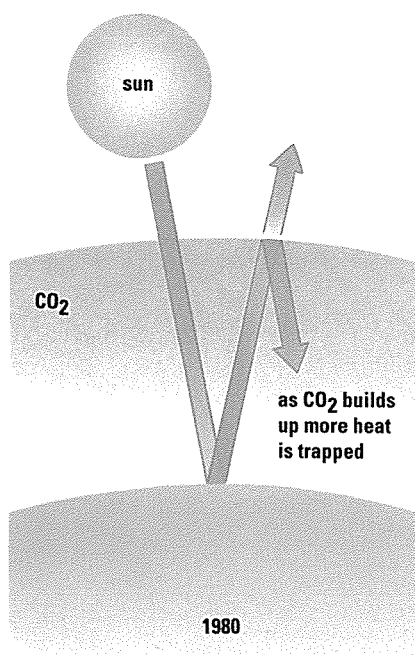
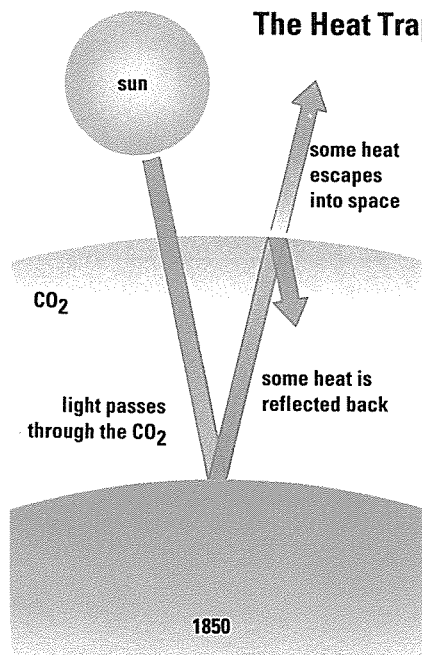
Plants take in carbon dioxide from the air, water and nutrients from the soil and use the Sun's energy to build living tissue by the process of photosynthesis. As a by-product of

The burning of rain forests to clear the ground for livestock pumps even more carbon dioxide into the atmosphere.

Vaughan Fleming/Science Photo Library



The Heat Trap



Joe Lawrence

Sunlight passes through the atmosphere easily, but heat is reflected back to Earth by the carbon dioxide (CO₂). Atmospheric carbon dioxide has been increasing steadily since the industrial revolution in the mid-1800s. The burning of the rain forests and fossil fuels – such as petrol – are inviting a global crisis in the 21st century.

Flooding in Asia was caused by eroded soil from deforested areas washing into the rivers until they burst their banks.

A thin layer of gases, including carbon dioxide and ozone, surrounds the Earth and makes 'life' possible. Infrared (heat) rays from the Sun pass through the atmosphere and are absorbed by the land and sea. Some of this heat is then radiated back into the atmosphere. But this radiation is of a longer wavelength and much of it is prevented from escaping by carbon dioxide and certain other gases. These gases thus act like the glass of a greenhouse, helping to keep the Earth warm.

For millions of years, this process

years. But open, agricultural land such as wheat or corn fields, or the wasteland produced when rain forest is cut down, reflects the heat back into the atmosphere. This 'mirror effect' could contribute to the overall global warming with grave consequences.

New bread-basket

If the tropical forests become vast grain-growing areas, this would act as a 'mirror' and reflect the Sun's warmth – which could then be trapped by the thicker blanket of carbon dioxide.

As temperatures rise and weather patterns alter, the world's current grain-growing areas such as in the USA and the former USSR could dry out and become deserts. At the same time, colder regions farther North would warm up enough to grow wheat and so – in theory at least – they could become the new bread-basket for the world.



JHC Wilson/Robert Harding Picture Library

burning of the rain forest has altered local climate. Once the forest disappears it becomes windier and drier. When rain does fall, the forest trees are no longer there to stabilize the shallow soil and soak up the moisture.

Instead, water runs straight into the rivers and causes floods. It carries the loose soil with it, which clogs the local waterways, irrigation channels and hydroelectric dams. The land is left bare, infertile and barren.

has maintained the temperature of the planet at a roughly steady state. The problem now is that the amount of carbon dioxide is increasing as human beings burn more wood, coal, petrol and other fuels. The global warming that results is becoming known as the 'Greenhouse Effect'.

The Earth's equator receives the most energy from the Sun. the jungles on the equator are dark green and absorb heat easily – and have been doing so for millions of



- GENETIC CODES
- MAKING PROTEINS
- MUTATIONS

EVERY INDIVIDUAL IS UNIQUE. And what makes every individual unique is a series of long molecules known as DNA (deoxyribonucleic acid).

Threads of DNA are found in the nucleus of every living cell and they are called chromosomes. In a human being the length of a single thread can be almost 1 metre when it is unravelled. Threads of DNA act like computer discs, storing the huge amount of information needed to make a human being, a dog, a pig, a sweet pea plant or whatever, depending on which organism they are taken from.

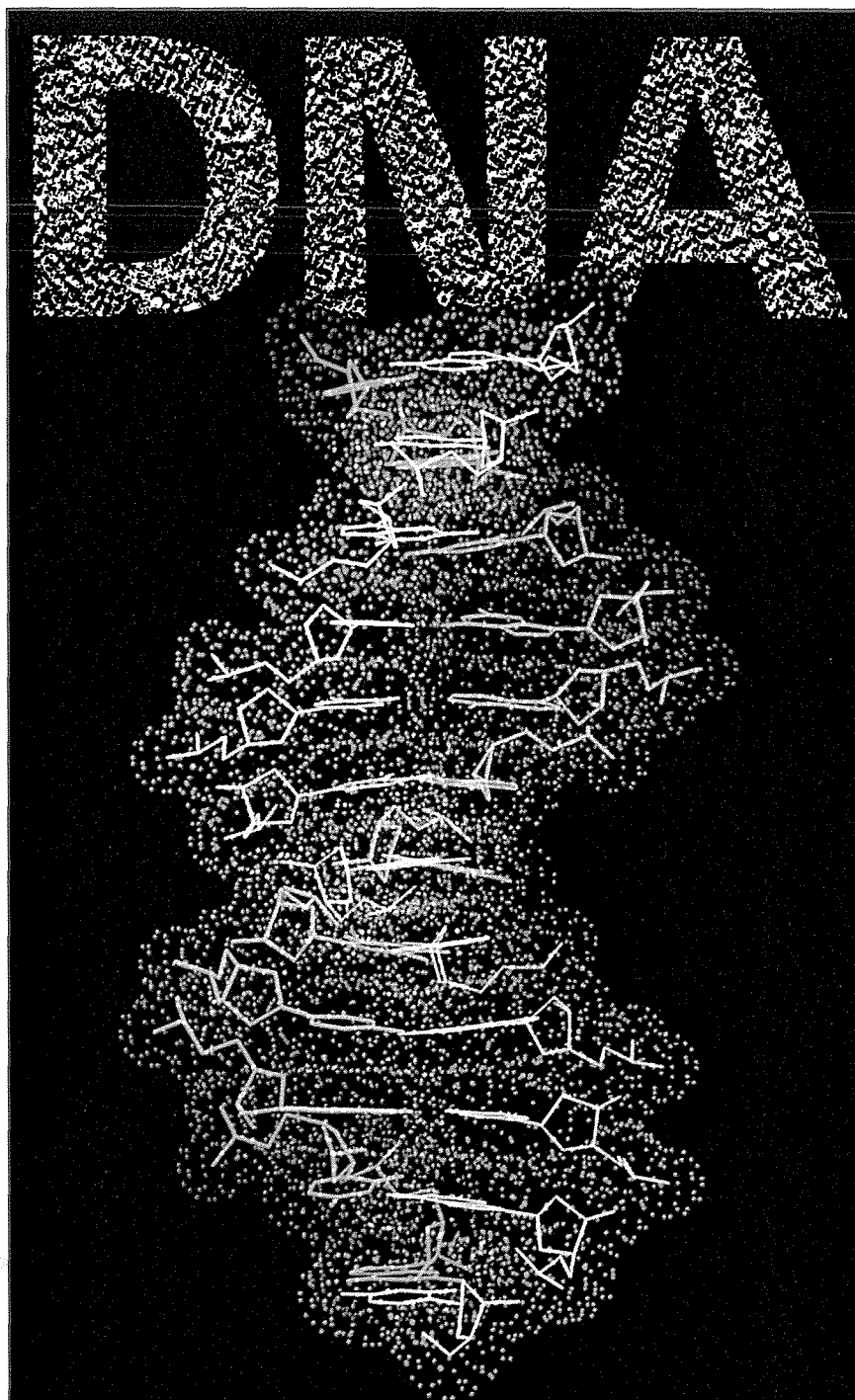
Replication

What makes DNA the very stuff of life are its ability to replicate and to be decoded into the proteins that help to make up a living being.

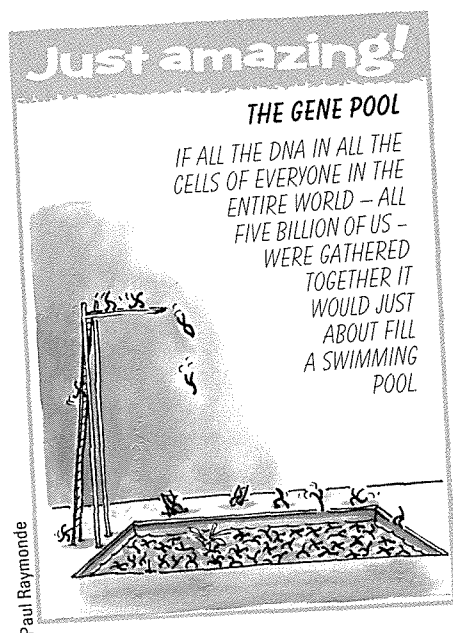
In a living, growing organism, new cells have to be produced. This is done by old cells dividing in two. Shortly before this happens, the two strands of the DNA double helix (a helix looks like a screw-shaped coil) uncoil and chemically replicate. The DNA molecules then coil up upon themselves and the chromosomes begin to look like the familiar 'X' shape. The two sets of chromosomes move to opposite sides of the cell, which then divides, with each new cell carrying a complete set of chromosomes contained within the nucleus.

A human chromosome carries around 80,000 genes. These carry

A strand of DNA coiled in a double helix, as revealed by false-colour computer graphics.



Oxford Molecular Biophysics Laboratory/SPL



MOLECULE OF LIFE

the coding for the thousands of proteins that make up the human body. Simple organisms have fewer genes.

In many organisms, chromosomes come in pairs. The fruit fly has four pairs, the chicken has 39 pairs and Man has just 23 pairs – 46 chromosomes in all. These 46 chromosomes appear in the nucleus of every cell in the body – except the sex cells. Sperm cells and egg cells have only 23 chromo-

somes each – so when the sperm penetrates the egg during reproduction, the resulting cell has the full complement of 46 chromosomes. The combination, though, is new and defines a complete, new, unique individual – their sex, their hair colour, the colour of their eyes, etc. It could even mean that they are an albino, with white hair and pink eyes. This is caused by a single gene mutation that is quite common, being found in one in 50 of us.



BODY TALK

Cell The smallest unit of life that can exist on its own, the building block from which all plants and animals are constructed.

Chromosome A thread-like structure, a number of which are found in the nucleus at the centre of every cell.

DNA (deoxyribonucleic acid) The chemical that makes up a chromosome.

Gene A tiny part of a chromosome. Genes control inherited characteristics.

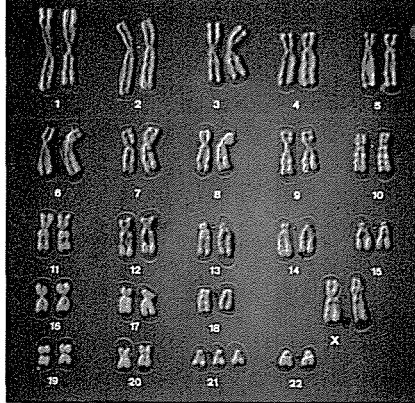
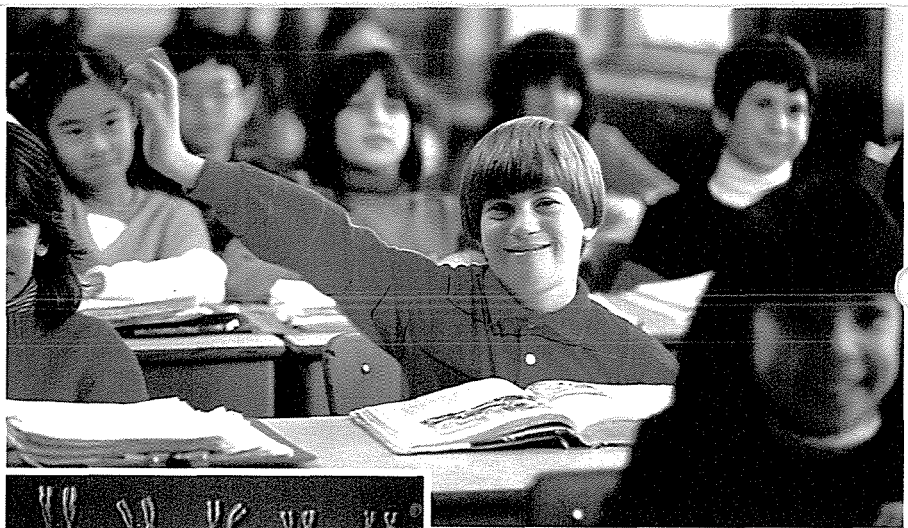
Sperm and egg The male and female sex cells, which join to form a new individual.

However it only rarely has any effect. Albinos have no melanin — the colouring agent in skin, hair and eyes.

At any stage of DNA replication a mistake may be made. Sometimes a gene is radically altered, either by errors in replication or by outside agents like prolonged exposure to

DNA is a strand of protein found within chromosomes, the long thread-like bodies inside the nucleus of every living cell.

Richard Hutchings/SPL



An extra chromosome in pair 21 of these matched pairs of human chromosomes is a sign of Down's Syndrome. Sufferers (such as the boy above) are born with low IQs and die young. However, they respond well to teaching and have loving natures.

are formed in the shape of a sickle rather than a disc. This means they break up more easily and get stuck in smaller blood vessels. The gene that causes sickle-cell anaemia is passed from parent to child and up to 100,000 people die from the disease each year.

There are other forms of genetic disease too. Down's Syndrome is caused by the existence of a whole extra chromosome. This gives those affected their distinctive features and makes them mentally retarded. Their IQs range from 30 to over 70 (the average for normal people is 100).

ultraviolet light, X-rays or radioactivity. These changes are called mutations.

If a mutation occurs that affects a sex cell, it may be passed on from generation to generation. If the mutation is helpful, the individual will flourish and its offspring will spread — this is the mechanism of evolution. But if the mutation is unhelpful, a genetic disease may spread down the generations.

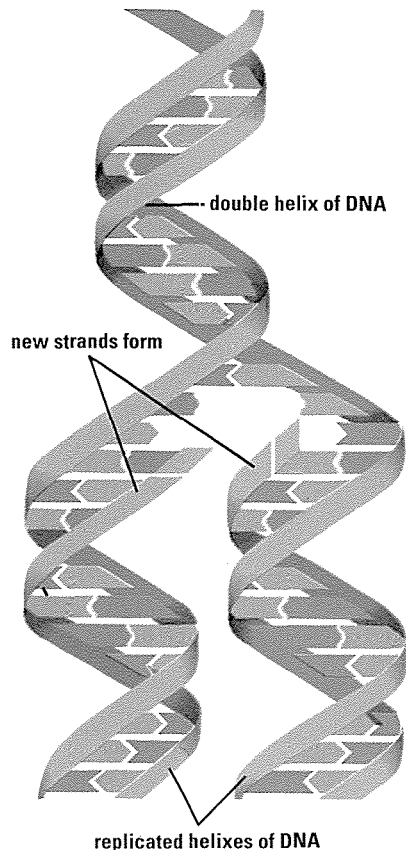
One example is the blood disorder sickle-cell anaemia, which mostly affects Mediterranean and African people. The red blood cells



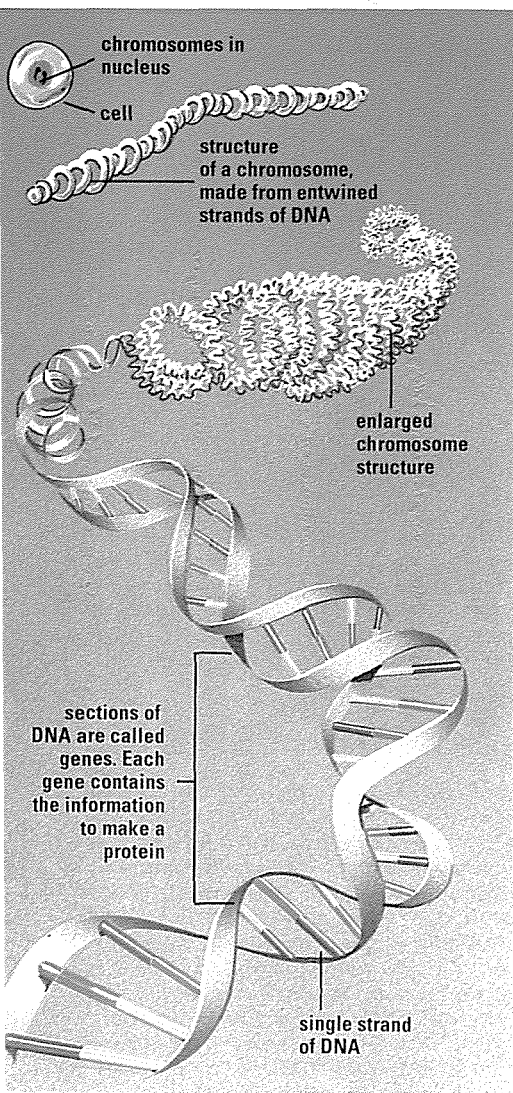
The Indian Muntjac deer has the least chromosomes of any mammal. The female has six, the male seven.

When DNA uncoils, it is chemically replicated. Matching proteins copy the sequence of the strand.

Jane Burton/Bruce Coleman Ltd



Caroline Brodie



- PLASTIC POLYMERS
- ORIGIN OF WATER
- A PINCH OF SALT

A lithium atom with electrons (blue) circling the central nucleus of protons (red) and neutrons (green).

David Parker/SPL

BONDING

EVERYTHING ON EARTH, including ourselves, is made up of tiny atoms – building blocks that fit together in many different ways. These atoms are each less than one ten millionth of a millimetre in size.

Groups of atoms joined together are called molecules. Oxygen atoms, for instance, can combine with each other to form oxygen molecules, or with hydrogen atoms to form water molecules. Molecules consisting of atoms of two or more different elements (such as oxygen, hydrogen or carbon) are called compounds.

Compounds can be quite simple substances with only a few atoms per molecule, as in water or salt. But some compounds, especially those found in plastics and in plants and living creatures, can have large and very complicated molecules as in substances known as polymers. Natural polymers include cellulose, resins and rubber; synthetic polymers include plastics such as nylon,

polyurethane and polythene.

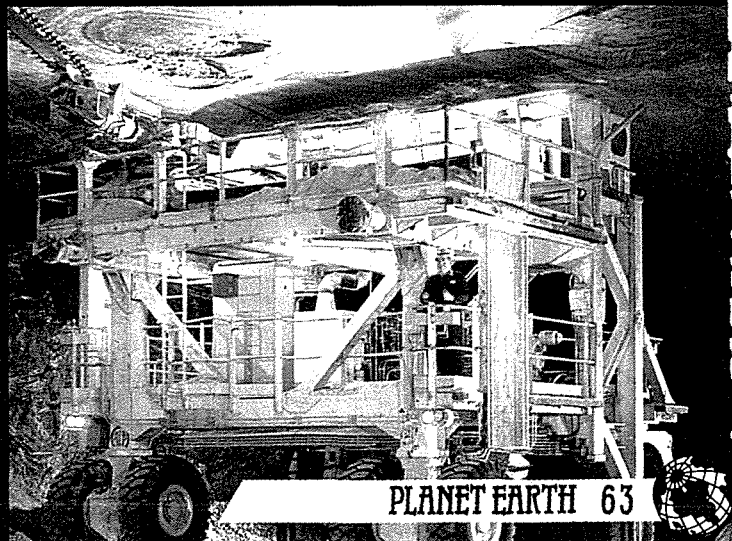
Inside every atom is a central core – the nucleus – which is a tiny clump of particles called protons and neutrons. The number of protons and neutrons in the nucleus varies from one element to another. A carbon atom, for instance, has six protons and six neutrons, while an oxygen atom has eight protons and

eight neutrons within the nucleus.

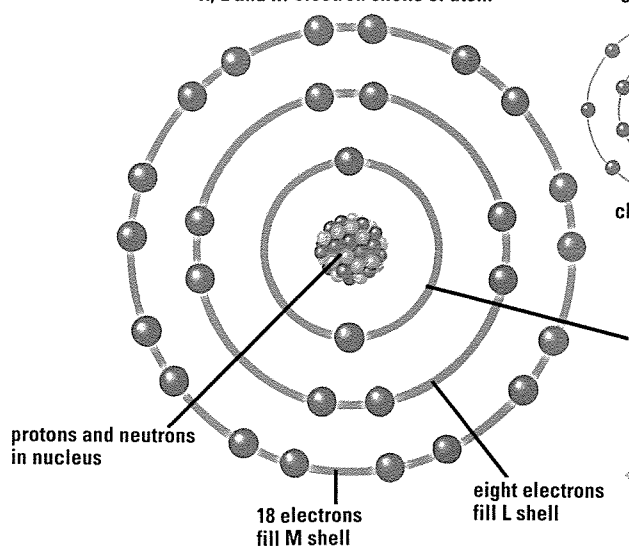
The nucleus of an atom is surrounded by a cloud of even smaller particles called electrons, and there is one electron for every proton. Each proton has a positive electric charge, and each electron has a negative electric charge. Because there are equal numbers of protons and electrons, their electrical

ICI Chemicals & Polymers

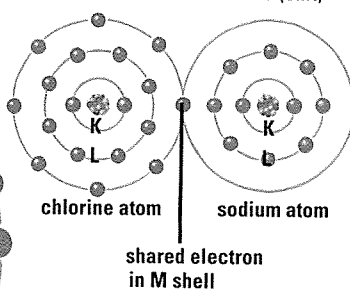
Rock salt is cut out of the underground salt beds in large blocks. These are crushed and sorted into different grades. By the use of anti-freeze agents salt is now being used outdoors and uncovered without hardening into a solid mass again.



K, L and M electron shells of atom



sodium chloride molecule (salt)



Caroline Brodie

— the kind you put on your food.

A sodium atom has 11 electrons, two in its K shell, eight in its L shell and one in its M shell. A chlorine atom has 17 electrons, two in the K shell, eight in the L shell and seven in the M shell. When sodium and chlorine combine to make salt, each sodium atom gives its single outer electron to a chlorine atom.

This leaves the sodium atom with one electron fewer than its number of protons, so it then has an overall positive electrical charge. The chlorine atom, however, now has one more electron than its number of protons, so it has an overall negative charge. The two atoms are thus attracted to each other.

The electron shells of an atom — known as K, L, M, N, O, P, and Q shells — can only hold electrons if the adjacent inner shell is 'full up'. Each shell holds a different number of electrons.

charges balance and so, overall, the atom has no electric charge.

The electrons are arranged in a series of concentric orbits or 'shells'. The way in which an atom can combine with other atoms to form molecules depends on the number of electrons in its outermost shell.

The electron shells are known as the K, L, M, N, O, P and Q shells, proceeding outwards from the centre of the atom, and there is a maximum number of electrons that can be in any one shell. The K shell, for example, can hold two electrons, and the L shell (the next one out) up to eight.

Sharing electrons

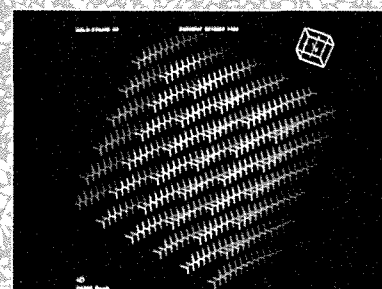
The process of atoms forming molecules by sharing electrons is known as covalent bonding. Because an oxygen atom has eight protons, it also has eight electrons. Two of these fill up its K shell, and the rest go into the L shell. But the L shell can hold up to eight, so it has room for two more. It will try to fill the vacant spaces in the shell and one way to do this is by sharing electrons with other atoms — for instance with hydrogen atoms.



Plastic film is made by calendering — the plastic is melted before being squeezed and stretched on rollers.

ZEFA

A CHAIN OF ATOMS



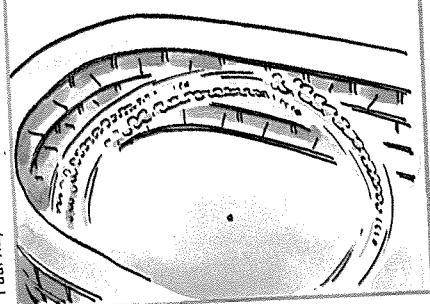
Small groups of atoms that are repeated over and over again like links in a chain are called polymer molecules. A single polythene molecule, for instance can be a long chain of over 25,000 carbon atoms, each with two hydrogen atoms bonded to it. This makes the material easy to work.

Chemical Design Ltd Oxford/SPL

Just amazing!

NUCLEUS ONE, ELECTRONS NIL

IF THE NUCLEUS OF AN ATOM WAS A PEA IN THE MIDDLE OF A FOOTBALL PITCH, SOME OF ITS ELECTRONS WOULD BE ORBITING AROUND THE EDGE OF THE STADIUM — SO GREAT IS THE DISTANCE BETWEEN THEM.



Paul Raymonde



ROCKS OF AGES

■ LAYERS OF ROCK

■ THE FOSSIL TRAIL

■ RADIOACTIVE CLOCK

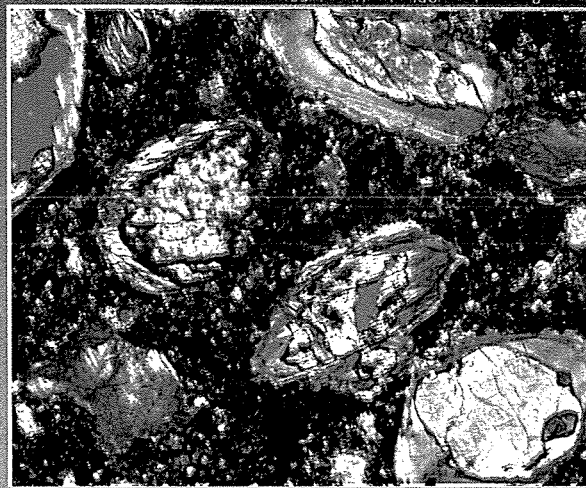
PLANET EARTH IS A RESTLESS beast. Nothing could seem more solid and durable than the mountains and the land. Yet, viewed over millions of years, mountains are born and die, oceans advance and recede, while whole continents drift, rotate and collide.

You can often see a small cross-section of the Earth's crust exposed. This happens in cliffs, in the rocky sides of a quarry, or a valley, or in an outcrop of rock that is bare of soil. Often the rock has a clearly visible layered structure. Each of these layers is called a stratum (more than one are 'strata'). The strata are often tilted or folded but each was originally level.

Sedimentary rocks

A stratum begins as a layer of sediment — silt, sand or both — under a body of water. The water might be an ocean, a river estuary or a swamp. In time, further layers of sediment build up. The colour and texture of these layers varies according to the composition of the sediment and the speed at which it is deposited. Eventually, a stratum is compressed by the huge weight of the rocks above. The grains of sediment are cemented together by minerals deposited from water, turning the sediment into rock.

Later, over immense periods of time, the strata may be affected by upheavals in the Earth's crust. They may be folded and tilted and raised above the sea, where they will be eroded by wind, weather and flowing water.

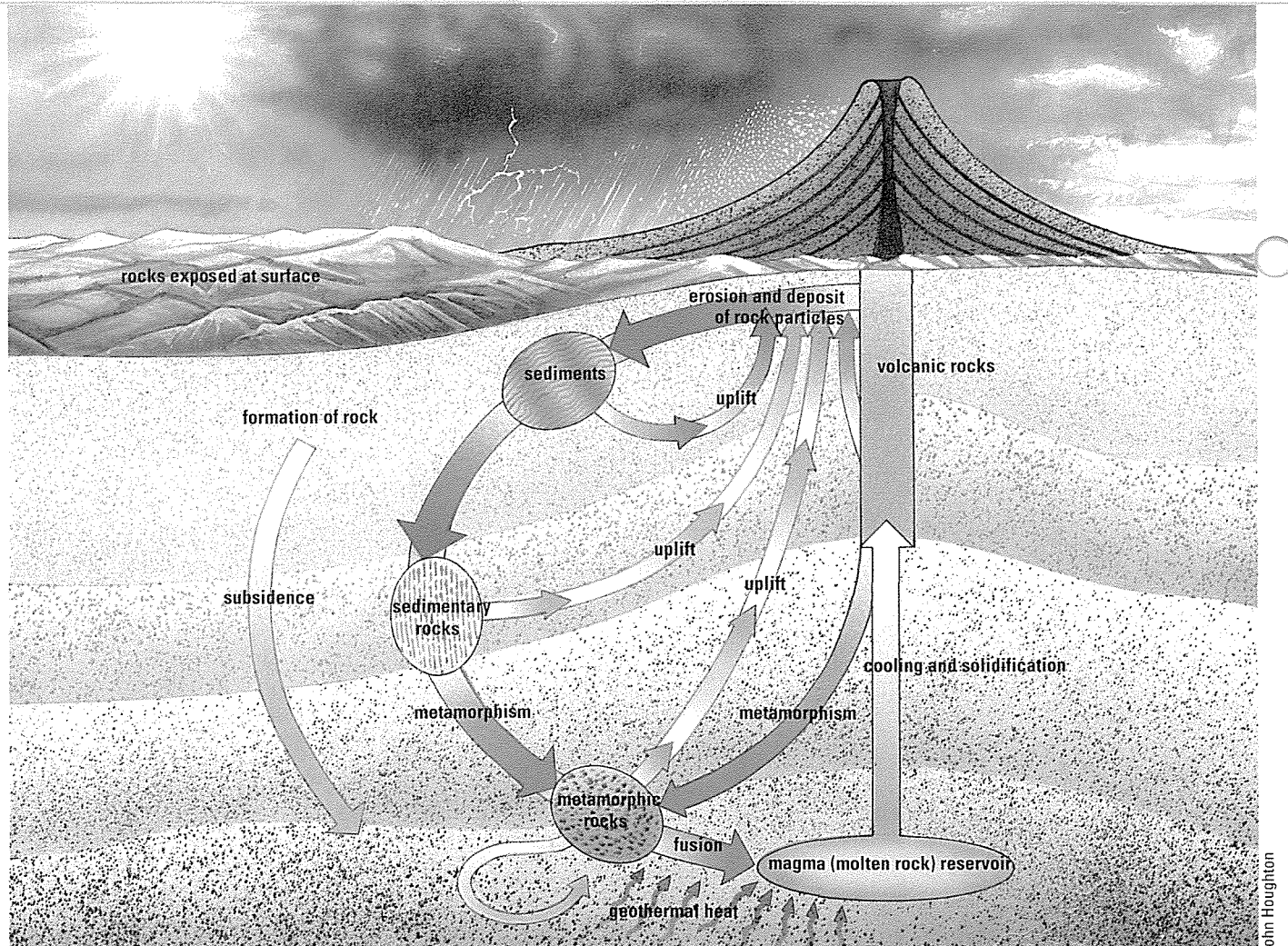


The creation of rock, exploding from a volcano and flowing in an unstoppable 1,000°C river.

Crystals of a volcanic rock called augite, photographed through an electron microscope.

Soames Summerhays SPL, Jan Hinsch/SPL



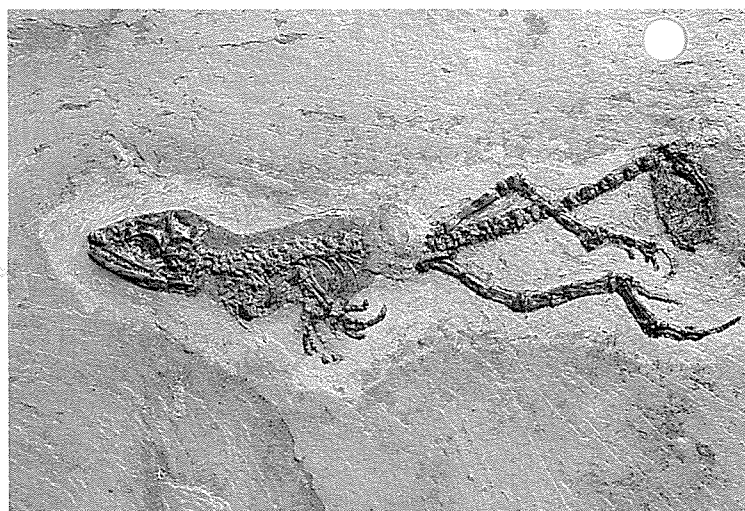
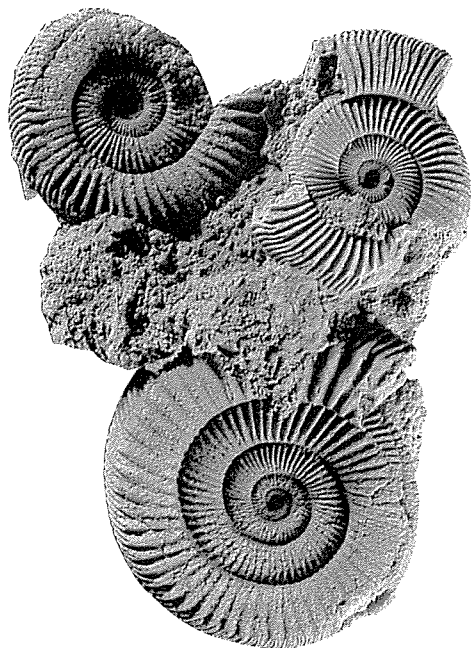


Although nearly all sedimentary rocks look as if they are made like a layer cake, most of the Earth's strata do not actually lie in neat, regular layers. Rock strata may plunge beneath the surface in some places, then reappear far away. In places like coastal cliffs or river canyons, they may have been worn away completely. But strata in one location can often be identified with those found elsewhere. A clue to identification is given by fossils.

The Earth's rocks
move around in a
perpetual cycle,
changing from one
form to another as time
passes.

Fossils, such as this ancient reptile, are the remains of animals or plants, preserved in stone over millions of years.

Ammonites are shelled animals that lived between 200 and 70 million years ago and are very useful in dating rock strata.



Fossils are remains or traces in the rock of once-living creatures. They may consist of bones or shells that have been turned into rock by chemical processes. Very occasionally, soft tissues may be fossilized. Alternatively, fossils may consist of holes or impressions in the rock, left behind when the creature's remains were dissolved and washed away. They can even be animal footprints or trails.

Dating fossils

Many different creatures have come and gone in the Earth's history, so the fossils in a rock stratum help to date it. In turn, when a new type of fossil is found, it may be dated by

identifying the stratum.

The study of strata and their fossils is one of the methods of 'relative dating'. This can reveal the *order* in which events happened and which rocks are older than others. But in itself, it does not provide 'absolute dating' – it does not, in other words, tell geologists how old a rock is in years.

Also, many rocks are not sedimentary – they are not formed from sediment. These are formed when molten rock from the hot depths of the Earth cools and solidifies, either underground or on the surface. Such rocks are known as igneous rocks. They do not form strata and, although it is often

zircon, found in Western Australia, are claimed to be the oldest known rocks on Earth, with a measured age of nearly 4,300 million years. The Earth itself is thought to have been created about 4,600 million years ago.

Carbon dating

Radioactivity can also be used to measure comparatively short periods of time — a mere few thousand years. The technique is popularly called carbon dating. The key to this is a radioactive form of

The Grand Canyon in Arizona, USA, is a 1 km-deep gash in the Earth's crust; it exposes 12 major layers of rock that once lay beneath sea.

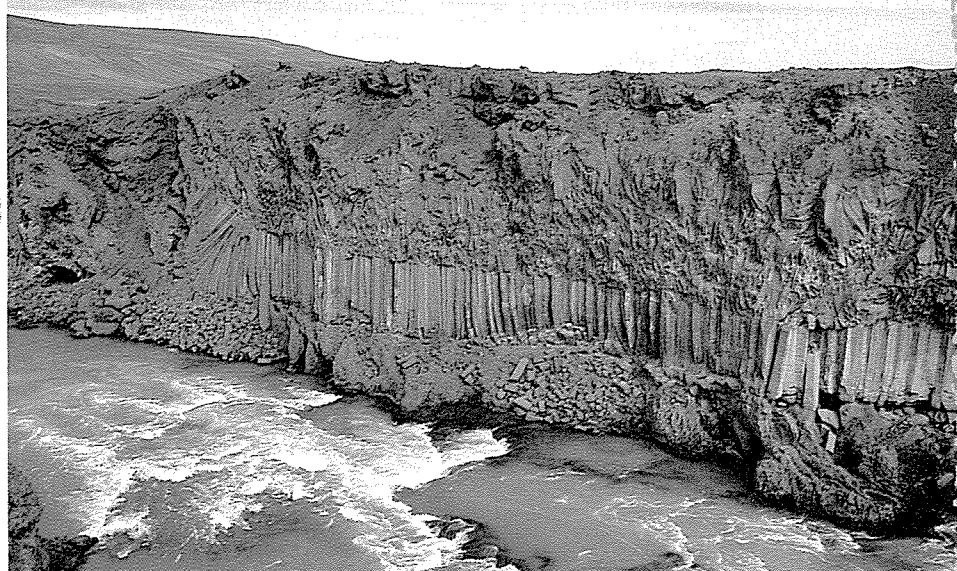
Spectrum Colour Library

possible to relate them to strata that they have covered or otherwise disturbed, there is still the problem of absolute dating.

Fortunately, the solution is provided by radioactivity, which can be used as an extremely accurate 'clock'. Radioactivity is present everywhere; there is a small amount in all rocks, as well as in the air and the sea. Radioactivity is caused by the atoms of certain chemical elements changing into atoms of other elements. When the element changes it sends out radiation.

For example, one type of potassium, called potassium-40, turns into argon-40, a gas. The process is called 'radioactive decay'. A rock

Simon Fraser/SPL



containing potassium would initially have contained little or no argon. Some of the potassium would be radioactive potassium-40. With time, as the potassium-40 decayed, the amount of argon would build up. So, measuring how much argon-40 and potassium-40 the rock now contains is a way of estimating the rock's age.

The key to the radioactive 'clock' is something called the half-life. The half-life of any radioactive element is the time that it takes for half of any quantity of it to decay. The half-life of potassium-40, for example, is 1,300 million years. So, if you took any quantity of potassium-40, small or large, 1,300 million years later you would find that only half of it was left. The rest would have decayed into argon.

The oldest rocks

Similarly, it takes 4,500 million years for half of a quantity of uranium-238, another radioactive element, to decay into one type of lead. So, measurements of such radioactive elements can be used for measuring the ages of very old rocks. Some crystals of the mineral

Volcanic rocks formed from surface lava sometimes cool into hexagonal columns, as seen on these cliffs.

Radioactive dating enables geologists to determine the age of volcanic rocks with a great degree of accuracy.



John Reader/SPL



Paul Raymond



CLUES FROM POTTERY

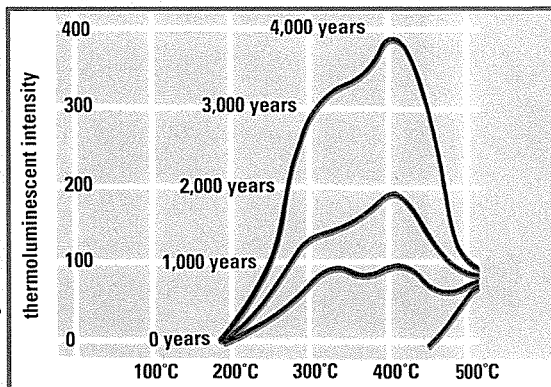
Side by side with the geologist's task of constructing a history for the rocks of the Earth is the archaeologist's task of constructing a history for human beings and their tools and possessions.

One of the commonest clues is pottery. The great durability of pottery means that it is one of the archaeologist's main sources of information about the past. The pottery's appearance and style can help pinpoint the culture and time it belongs to. Sometimes, however, the clues are not so obvious – only fragments, for example, may exist – and the archaeologist must turn to more sophisticated dating techniques.

One such technique relies on the fact that the position of the magnetic poles has changed over time; with magnetic north wandering from Northern Europe around 1,000 AD, eastwards across Siberia to a circular trip around the northern Pacific Ocean around 1,300 AD, skirting back past the North Pole around 1,600 AD then around the north-eastern corner of the North American continent and back towards the North Pole around 1,900 AD. Because baking

fixes iron particles facing the magnetic poles at the time of firing, pottery can be dated by referring to an index of the known positions of the poles.

Another, widely used, technique is known as thermoluminescence. This relies on the fact that some of the impurities baked into pottery are radioactive. By reheating pottery samples a faint light, or luminescence, is emitted. Measuring this light it is possible to obtain a precise age.



HMSO/British Geological Survey

John Houghton

A mass spectrometer is used to detect and measure radioactivity in rock samples to determine absolute age.

carbon – one of the most abundant elements on Earth – carbon-14. Carbon-14 is present as a small proportion of the carbon in the air. It is formed from nitrogen by the action of cosmic rays (high energy particles travelling through space) and is always found in the tissues of plants, which absorb carbon dioxide from the atmosphere.

When a plant dies, the carbon-14

COUNTING TREE RINGS

The counting of rings to establish the age of a tree is known as dendrochronology. In the early part of the growing season new growth is characterized by large, thin-walled cells that make the wood appear light whereas later growth is characterized by smaller, thick-walled cells that make the wood appear darker. It is the contrast between the dark wood and the light wood of the next year's growth that make the rings. The rings are counted from the centre to the bark. Each ring equals one year.



P Morris

in it is no longer renewed from the atmosphere. It simply decreases as it decays into a form of the gas nitrogen.

Cosmic rays

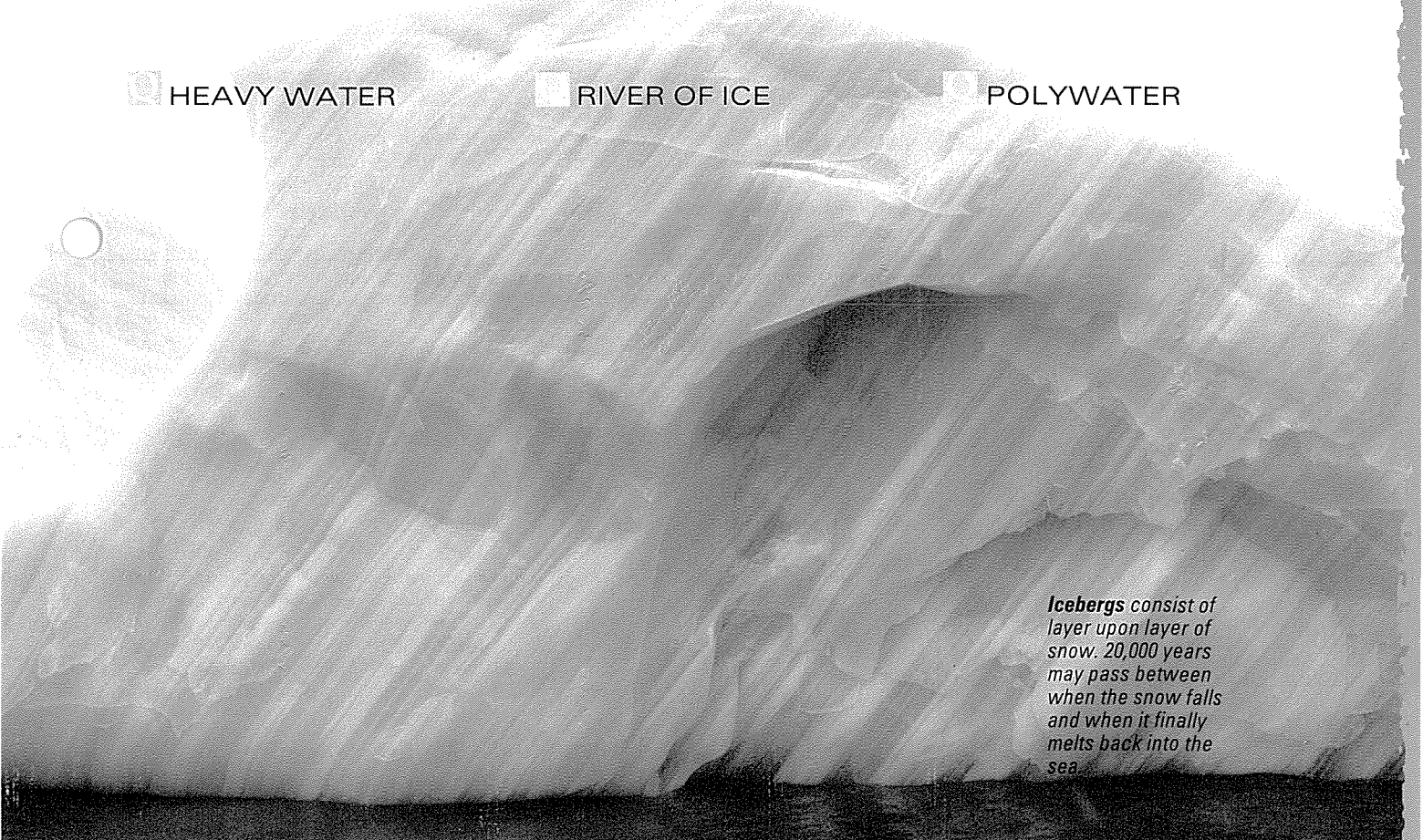
Measuring the amount of carbon-14 in dead vegetable matter can reveal approximately how long it is since the plant died – some allowance has to be made for possible changes in the amount of carbon-14 in the atmosphere in the past. Such changes occur when the amount of cosmic radiation bombarding the atmosphere alters –

associated with increases in sun-spot activity.

The half-life of carbon-14 is 5,730 years. Using this fact some rock deposits dating from the last ice age, which ended 10,000 years ago, have been dated by plant matter found in the rocks. Human beings, physically essentially the same as modern people, were flourishing then. Items such as cloth of papyrus, can be dated by the carbon-14 method. Several different radioactive dating methods are used, enabling scientists to piece together the puzzle of the Earth's history.

Spectrum Colour Library





HEAVY WATER

RIVER OF ICE

POLYWATER

Icebergs consist of layer upon layer of snow. 20,000 years may pass between when the snow falls and when it finally melts back into the sea.

FANTASTIC FLUID

THERE IS NO SUCH THING AS ordinary water – every drop is extraordinary. Among other things, it's the only everyday substance that exists in all three physical states of matter – solid (ice), liquid (water) and gas (water vapour).

Even the supposedly pure liquid that you drink every day is a mixture of two completely different types of water – light water plus very small amounts of heavy water. The heavy variety weighs 10 per cent more than the same amount of ordinary water and so you would have no difficulty floating in a bath of it.

Two atoms of hydrogen and one atom of oxygen combined together form water. But the hydrogen in heavy water is very different from ordinary hydrogen.

The nucleus of an ordinary hydrogen atom contains one proton. When the nucleus also contains a neutron, the atomic mass is doubled and the atom becomes the heavy isotope of hydrogen called deuterium, which makes heavy water.

Heavy water is used in atomic reactors to slow down neutrons and so control the amount of heat produced. Some atomic reactors

are also filled with heavy water to ensure easy access to the uranium fuel rods without allowing the escape of radioactive particles.

Strange behaviour

Water is also just about the only substance in the world that ever expands – gets larger – as the temperature falls. Nearly everything else contracts – gets smaller – as this happens. It works like this.

Water behaves normally and contracts down to a temperature of 4°C. If the temperature falls below that, water expands until it reaches 0°C. Water normally turns into ice at that point and expands again.

If a rare substance like gold behaved like this, it wouldn't really matter. But as three quarters of the Earth's surface is covered with water and all living things need it to stay alive, the strange behaviour of water is very significant.

Warm bottom

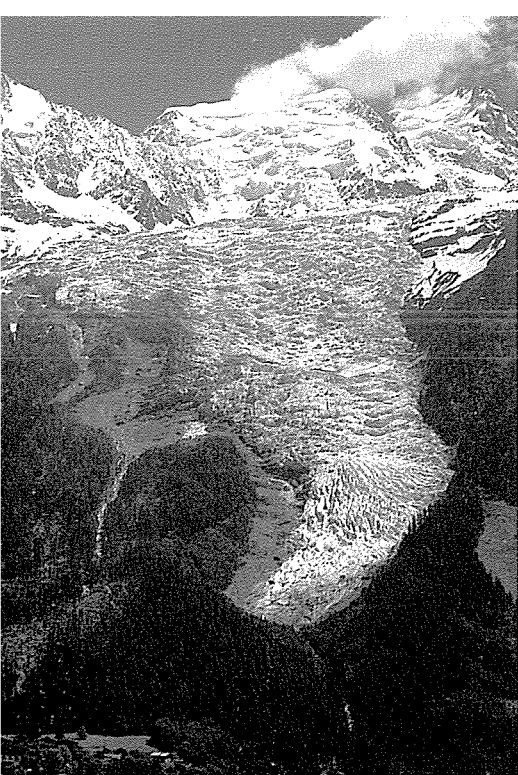
Indeed, lots of animals that live in water owe their very existence to the fact that water is at its heaviest at 4°C. When it falls below that temperature, water floats to the surface, so ice always forms on the surface of a pond or the surface of the sea. It doesn't form at the bottom as you might expect from

Atomic reactors are sometimes filled with heavy water. This is ten per cent heavier than ordinary water. Heavy water slows down any neutrons passing through it and is often used as a radiation shield around reactors to protect the people working on them from radioactivity.

ZEFA

Tony Stone Photo Library, London





Simon Fraser/SPL

Glaciers rip chunks out of the underlying rock. When a glacier melts, this rock is dumped at the bottom of the mountain.

the way that other liquids behave.

As a result, the water at the bottom of a pond stays at 4°C. Fish and other marine animals live out the cold weather in this warm layer and normally survive until the ice above melts and everything goes back to normal. They only get frozen, and so die, if the water freezes solid right through.

Burst pipes

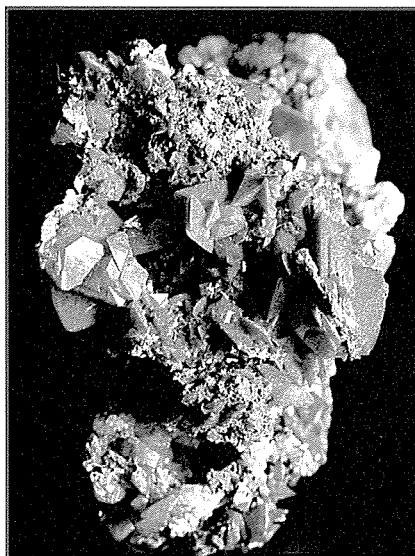
This is fine for the fish, but the way that water expands when it freezes can create problems. Nine litres of water expands into ten litres of ice and the forces behind this are immense. The thin copper pipes that carry drinking water around your home simply can't stand up to the pressure and they burst. When the temperature rises, the ice in the pipe melts and water pours out.

Water also absorbs an unusually

large amount of heat before it boils. This makes it very good for transmitting heat around a house via the central heating system and for cooling things like car engines. But car engines and radiators can burst in the same way as water pipes if the water freezes.

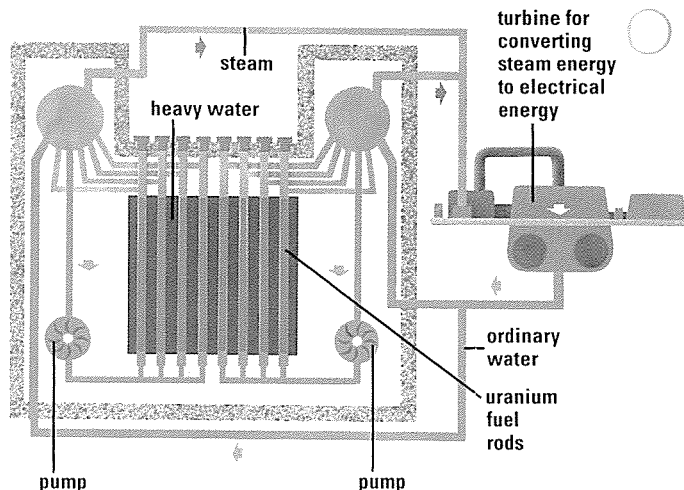
The way round this is to add ethylene glycol – antifreeze – to the water in the radiator. This freezes at -13°C and so reduces the temperature at which the engine freezes.

In fact any impurity added to



Liroconite like many other crystals, contains molecules of water locked up in the lattice structure of the crystal.

Uranium fuel rods in nuclear reactors generate neutrons which are slowed by the surrounding heavy water. The heavy water level controls the amount of steam generated.



Heavy water plants are built at electricity generating stations because the process of separating heavy water from light water takes an enormous amount of electricity. Most heavy water is used to control – moderate – the amount of heat produced by atomic reactors. It is mostly produced in Canada where electricity is cheap.

ON THE EDGE

The edge of a skate blade is not a knife edge but is about 3 mm wide, so an adult weighing 60 kg generates a pressure of 8 kg per square centimetre at the point where the blades touch the ice. The pressure melts the ice under the skate blade and so a film of water is created between the blade of the skate and the ice. This film lubricates the passage of the skate over the ice and allows a skater to whizz around the ice with the greatest of ease. The water film freezes over when the pressure of the skate edge is removed. If there are a great number of skaters on a rink, the ice can start to melt.

water affects its freezing and boiling point. So when your local council spreads salt on icy roads, it lowers the freezing point of the water and melts the ice. When salt is added to water during cooking, it raises its boiling point and the food cooks faster.

Under pressure

The boiling point is also affected by air pressure. Car cooling systems take advantage of this by having a working pressure up to a third higher than atmospheric pressure. Inside the radiator, water does not boil until the temperature

goes over 110°C. But if you undo the radiator cap while the engine is hot, the pressure inside the radiator goes back to normal and the cooling water immediately boils. Following this, a jet of hot water at about 110°C erupts out of the radiator.

Keeping cool

By running the cooling system at a high pressure and temperature, car designers can use a smaller radiator than would be required if the cooling system operated at normal atmospheric pressure.

On the other hand, reduced air pressure has the effect of reducing the boiling point of water. At ordinary altitudes, this has little effect. But in the high mountains, cooking



Atomic Energy of Canada

UKAEA/Janos Marffy



Sea ice covers large areas of the polar regions during winter, but life goes on underneath. If water froze from the bottom up, aquatic animals would eventually become trapped on the surface of the ice with an insufficient depth of water to keep them alive and no way of escape.

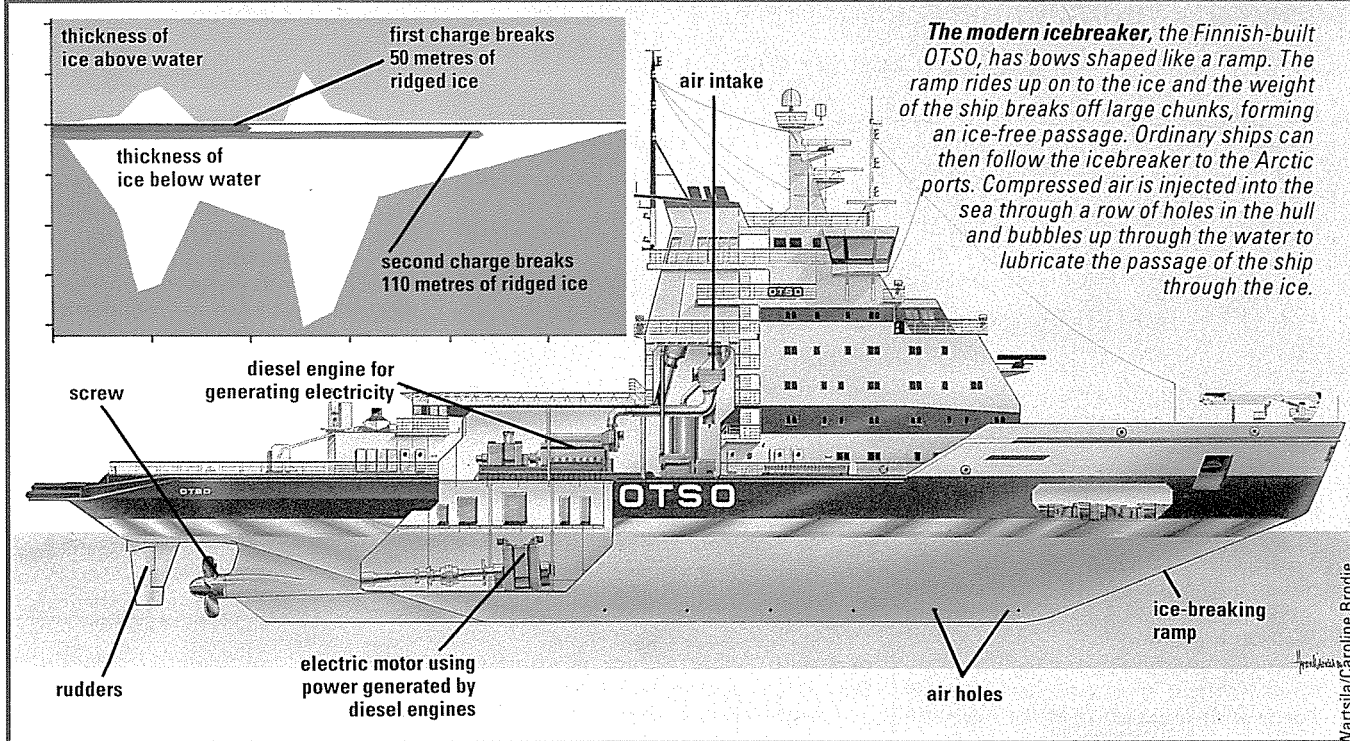
of up to about 19 metres per day.

Where the shape of the underlying land funnels the ice downhill, it becomes a river of slowly moving ice known as a glacier. At the bottom of the mountains, the glacier melts and becomes a river of ordinary but very cold water.

Parts of the polar ice caps are also glaciers — one Antarctic glacier is 400 km long. At the low polar temperatures, a glacier doesn't melt but keeps on going until it sticks out into the sea. At intervals the end then breaks off under its own weight and forms icebergs.

DIESEL-ELECTRIC ARCTIC ICEBREAKER

David Rootes/Planet Earth Pictures



The modern icebreaker, the Finnish-built OTSO, has bows shaped like a ramp. The ramp rides up on to the ice and the weight of the ship breaks off large chunks, forming an ice-free passage. Ordinary ships can then follow the icebreaker to the Arctic ports. Compressed air is injected into the sea through a row of holes in the hull and bubbles up through the water to lubricate the passage of the ship through the ice.

is very difficult and slow because water boils at around 70°C and so doesn't heat the food enough to cook it.

Below 0°C, water normally becomes a solid but if you scoop up a handful of snow and mould it together with your hands, a little of the snow melts and sticks the ice

crystals together into a snowball. So pressure reduces the temperature at which water freezes into ice.

When snow falls on a mountain, it builds up until the weight squashes the air out of the bottom layers. So much pressure is applied to the bottom layers that sheets of apparently solid ice move at speeds

Some icebergs are only ten or fifteen metres across and are known as growlers because of the noise that they make when they rub against each other. On the other hand, the largest iceberg ever sighted was larger than Belgium. Another was tracked for 17 years before it finally melted away.

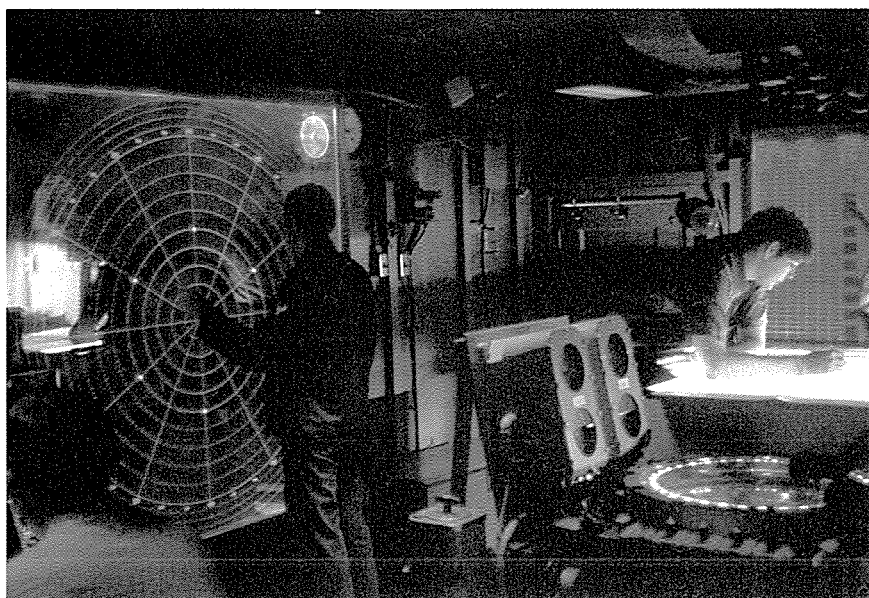
Towing icebergs

Ice is lighter than the water it floats in, so only one-ninth of the height of an iceberg shows above the surface. An iceberg stretching 60 metres above the water actually extends 480 metres below.

Many ideas of using these chunks of frozen water have been dreamed

Submarine navigation stations are dominated by enormous cathode ray tube (CRT) sonar displays. The positions and range of all nearby ships are displayed so that the submarine commander can plan his route through the escort ships, make his attack and escape.

Frank Spooner Pictures



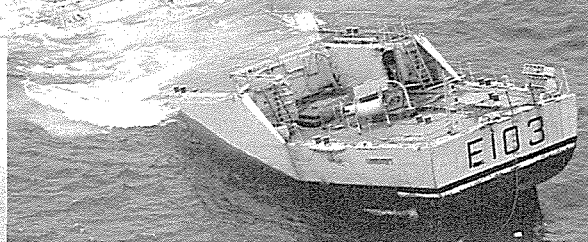
up and some may eventually be used. The most popular one is the notion of towing icebergs to areas that are desperately short of fresh water like the Persian Gulf. Once there, the bergs will melt in the sun and the water will be collected for drinking. The water in icebergs is so pure that it is entirely safe for drinking.

Another idea is to mix ice with wood shavings to form a material called pikecrete. Icebergs would

Marconi Underwater Systems



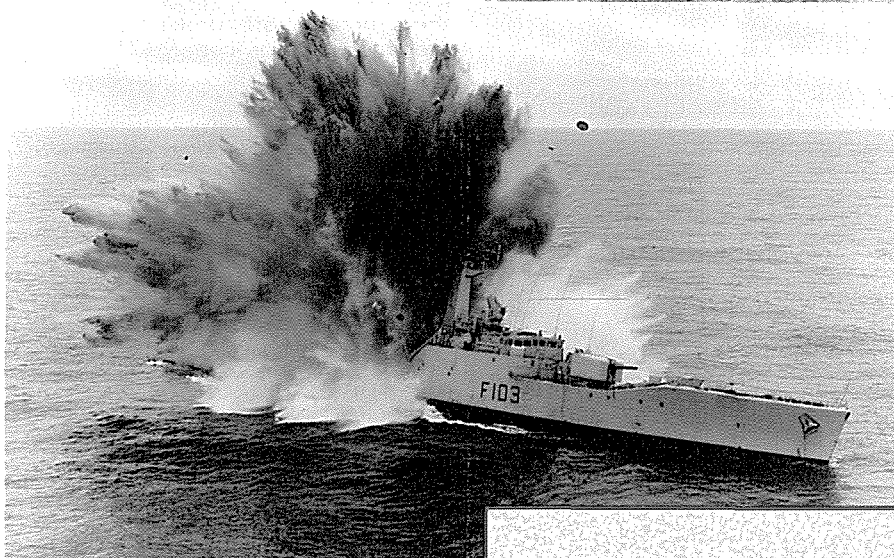
Stingray is a lightweight torpedo which can be launched by ships or aircraft. An acoustic receiver is fitted into the nose which detects Sonar and propeller noises from enemy ships and submarines. Using this information, it homes on to the target with great effect.



presented on a screen so the commander can plan his attack.

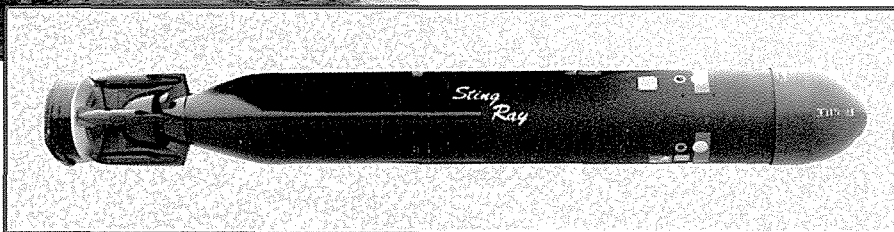
Propeller noises also travel enormous distances through water. To combat this, warship and submarine propellers are carefully designed to minimise the noise that they create and to make as few bubbles as possible. Highly sophisticated machine tools are required

Marconi Underwater Systems/TRH



supply the raw material and a raft of Pikecrete could be towed anywhere to serve as an artificial harbour or emergency landing strip in mid-ocean. A freezer unit built on the deck of the pikecrete raft would prevent it melting.

At the swimming baths, you may have noticed that you can hear all sorts of strange sounds through the water. In fact sound travels hundreds of times further through water than through air. Taking advantage of this, all submarines and most surface warships are equip-



ped with Sonar, which is short for Sound Navigation And Ranging.

A high-pitched pulse of sound is sent out into the water by the Sonar apparatus. This pulse bounces back off anything solid, such as surface ships or other submarines, so the echoes can be picked up by an underwater microphone. This is very similar in principle to radar.

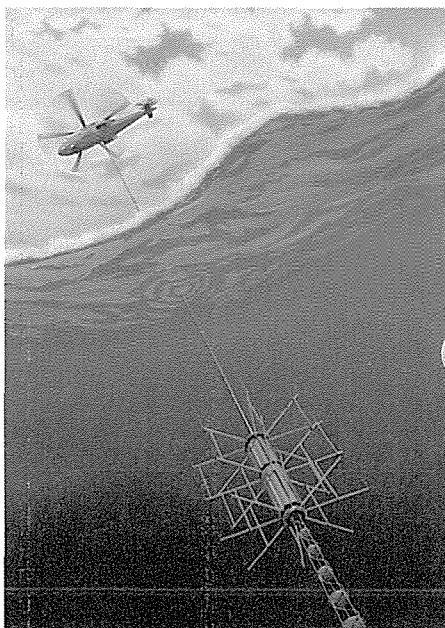
Echoes

The returning echoes are distorted as they pass through the different layers of the ocean — layers formed by water of different temperatures and saltiness. To eliminate some of this distortion, the echoes are processed electronically. The time taken for the sound to reach the other vessel and return indicates how far away the other vessel is. The resulting information is then

to cut the complicated shapes of these low noise naval propellers.

Not content with all these strange properties, scientists have come up with the theoretical possibility that one day, water molecules might start to behave like polythene molecules and join together — polymerise — into long chains. This Polywater would absorb all ordinary water. You could drink as much Polywater as you liked but it wouldn't quench your thirst or keep you alive.

Marconi Underwater Systems



Dipping sonars are carried by helicopters and enable them to search large areas of water for submarines. This type of Anti-Submarine Warfare (ASW) equipment is more effective than ship-borne Sonar because of the helicopter's speed and range, which allow it to search waters well ahead of the fleet.

British Aerospace

Just amazing!

MONEY DOWN THE DRAIN

IF YOU USED HEAVY WATER INSTEAD OF TAP WATER FOR WASHING, FLUSHING THE TOILET AND MAKING THE TEA, YOUR ANNUAL WATER BILL WOULD BE OVER £10,000,000!



Paul Raymond



TAKING THE

J Budge/Liaison/Frank Spooner Pictures

DRINKING

HEALING BATHS

SWIMMING FOR HEALTH

WATER THEME PARKS

WATER IS PROBABLY THE oldest medicine known to Man. Hippocrates, the father of modern medicine, used water and thermal springs to treat the sick of ancient Greece. Centuries later the ancient Egyptians worshipped the Nile for its apparent healing properties.

When used correctly and on specific parts of the body there is no doubt that water has a great healing value. It can be used either hot or cold. The different temperatures have different effects on the body. Each effect has a short, initial action which is followed by a more prolonged, secondary one. Furthermore, warm and cold water have very different actions.



Ice bag

In medicine these actions are used to treat many different conditions. For example, if you twist your ankle playing sport – an acute, or sudden, injury – the aim is to stop

Alexander Tsirlas/SPL



A tent of warm water covered by a thin plastic membrane lulls a baby undergoing an ultrasound scan of his kidneys.

A slide surfer, surfing down a water slide at Florida's Wet & Wild water theme park takes water thrills and spills to their limits.



the pain and reduce the swelling as soon as possible. Here you would use cold water in some form. Ice is best, although it should never be applied directly to the skin because it would stick and 'burn'.

A bag of frozen peas is ideal, but a cold towel or even a cold can of soft drink can just as easily be used. Place the cold pack over the damaged area for at least 15 minutes; this allows the secondary effects to take place (see HOT AND COLD WATER PACKS).

The 'Blue Lagoon' at Svartsengi, Iceland, is heated to 70°C by waste water from the power station. The heat and dissolved particles of volcanic rock help to relieve bathers suffering from skin diseases.



An athlete, being treated for an injury with chlorinated cold water agitated by bubbles in a hydrotherapy bath at the Crystal Palace Sports Injury Centre, North London.

If you have a long-standing injury (a chronic condition) it is best to use alternate hot and cold water. Normally towels, soaked in hot and cold water, are applied directly to the damaged area, but a shower hose may be more convenient. The hot water relaxes the area and brings blood to it. The cold water kills the pain and 'flushes' the area with fresh blood. The overall effect is pain-killing, relaxing and healing.

Bath time

Water treatment, or hydrotherapy, can take many forms. The most common are:

- Full immersion cold bath — this is used to help control fevers (only under specialist advice and control)
- Full immersion hot bath — this is used for a short time only (2–10 minutes) to treat poor circulation
- Water jets (douches) — these are used locally or generally over the

body. They are best used with alternating hot and cold sprays — hot for 3 minutes, cold for 1 minute. They work in the same way as hot and cold packs but are more stimulating and have a stronger effect

• Epsom salt (magnesium sulphate) bath — similar to the hot immersion bath but epsom salts are added to the water. This relaxes tight muscles, and is particularly good after a strenuous exercise.

Hot springs

Many people with joint and muscle pains claim great relief after bathing in natural hot springs or pools. These are kept hot by the 'geothermal' heat generated within the Earth's crust.

The healing effects of hot springs were noted by an Italian-American man called Roy Jacuzzi who built a bath that artificially created the effects of a hot spring pool for his

FITNESS PROGRAMME

Swimming is excellent for the healthy body, exercising not only the joints and muscles but working the heart and lungs. The three main strokes work the following muscles: crawl and backstroke work shoulder, chest, upper back, and legs; and breaststroke works chest, upper back, shoulders, arms, neck and legs.

You must have at least the elementary swimming certificate before attempting this programme.

Week One: 1 length crawl, 1 length backstroke, 1 length breaststroke. Aim to swim about 12 length (400 metres).

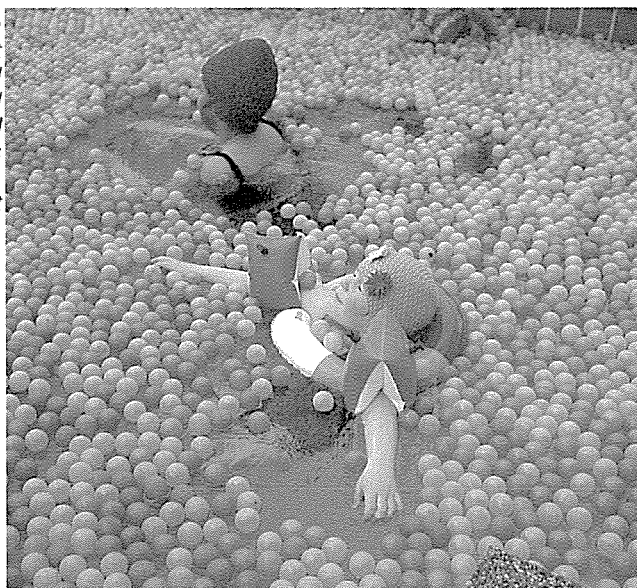
Week Two: 2 lengths crawl, 2 lengths breaststroke, 2 lengths backstroke. Aim to swim about 24 lengths (600 metres).

Week Three: As in week two.

Week Four: 3 lengths crawl, 3 lengths breaststroke, 3 lengths backstroke. Aim to swim about 36 lengths (1,200 metres) in total.

Never push yourself. If you feel tired STOP and REST and NEVER try to swim through muscle cramp or stitch.

A thermal bath in Ruppolding, West Germany is enjoyed by young and old bathers. The small plastic balls act as an insulation, helping to stop heat escaping.





Tony Stone Photo Library, London

TAKING THE PLUNGE

'Wet and Wild', rides are constructed that aim to use both height and water to create safe thrills and spills.

Excitement

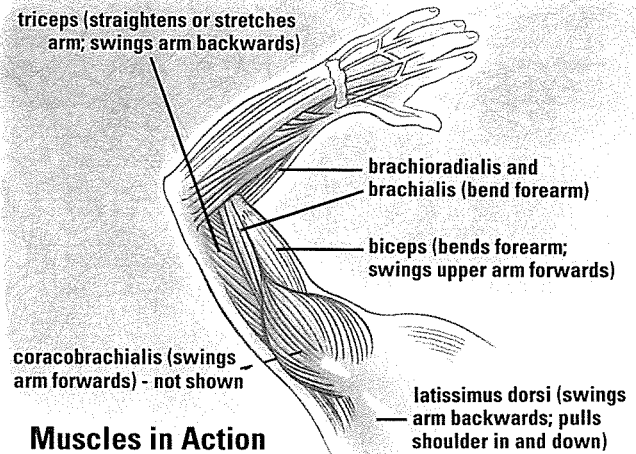
When you feel excited your heart pounds, breathing becomes rapid and you feel trembly. This is because your body produces a hormone called adrenalin. This hormone is made at times of stress to prepare your body to fight or run. When you are at the top of a water ride, about to plunge downwards your body releases lots of adrenalin in response to the fear of the

son who suffered with rheumatism. This bath, as well as containing hot water, also produced many jets of bubbly water. The hot water relaxed the muscles and soothed joints, while the jets massaged the arms, legs and back. The idea soon caught on and the Jacuzzi, as it became known, is now widely used for both therapy and relaxation.

One of the best therapeutic uses of water is swimming. In a swim-

Swimming works nearly every muscle in the body as well as the heart and lungs. In the front crawl, the main muscle groups worked (right) are those of the arms, shoulders and legs.

Water theme parks, such as Wet & Wild in Florida, USA, are designed to provide safe thrills and spills for water daredevils.



Muscles in Action

Mark Iley

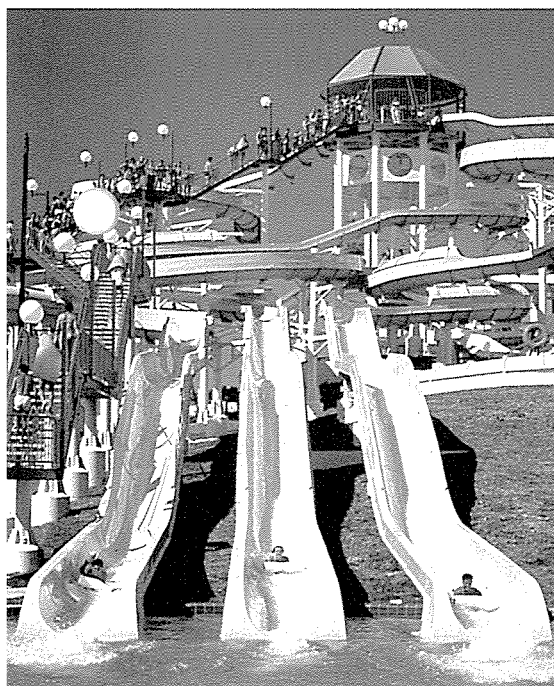
ming pool your body is supported by the water and the stress and strains of gravity are removed from your joints. This produces great relief for people with joint disease or injury. If combined with gentle exercise, a very effective rehabilitation therapy is created for both the old and people with joint and muscle disease. This type of hydrotherapy is used in hospitals by physiotherapists every day.

Water fun

Water is not only used for fitness and therapy — it can also be great fun. This element has been exploited in water theme parks. In places such as 'Aquapark' on Spain's Costa del Sol and Florida's

sudden drop and you feel excited.

Water is very hard if you land on it awkwardly in a painful bellyflop. This is because the molecules of water are packed very closely together. A feature of some water theme parks is the bubble pool. In it thousands of bubbles are pumped into the water to break up the hard surface. This means that you can land in the water any way that you want, jumping in wildly or performing outrageous bellyflops, without hurting yourself.



Wet'n Wild

PROFILE

HOT AND COLD WATER PACKS

COLD WATER

Initial effect

- Small blood vessels contract
- Skin becomes pale
- Shivering and some discomfort
- Sensation of chilliness
- Stimulation of nervous system

Secondary, longer lasting, effect

- Small blood vessels dilate
- Skin turns red
- Pain relief, relaxation and comfort
- Sensation of warmth
- Relaxation of nervous system

WARM WATER

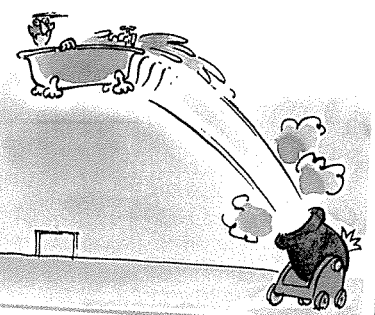
- Expansion of small blood vessels; blood rushes to area
- Stimulation of nervous system
- Muscular discomfort

- Extra amounts of blood are drawn into injured area
- Tiredness and drowsiness
- Muscular weakness and relaxation

Just amazing!

HARD WATER

A WATER CANNON THROWS MORE THAN FOUR BATHFULS OF WATER EVERY SECOND WITH ENOUGH FORCE TO KNOCK YOU OFF YOUR FEET AT THE OTHER END OF A FOOTBALL PITCH.





VIEW

WATERMOBILES

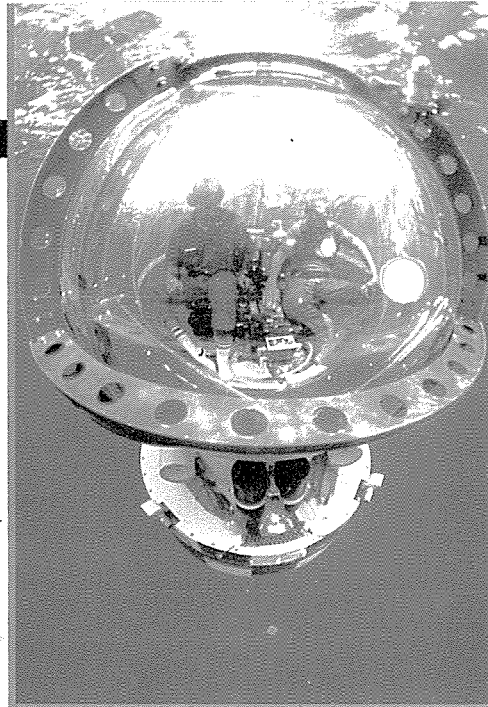
ZEFA



Flip Schulte/Planet Earth Pictures

The swamp buggy, is a flat-bottomed craft, powered by an aircraft propeller, specially designed to cope with the Everglades of Florida. They are also raced.

The clear sphere of the US Navy's N.E.M.O. – Naval Experimental Manned Observatory – provides an ideal view of life beneath the sea.



Quadrant Picture Library

Grey Iveco, an offshore power boat taking part in the British Cowes – Torquay – Cowes race, has two 10 litre, turbocharged diesel truck engines, producing 1200 hp and can reach speeds of 144 km/h.

A glass bottom boat, here on the Red Sea in Israel, is one of the best ways to observe life beneath the sea without getting your feet wet. Renowned for its clarity, the Red Sea is highly prized by sporting divers and marine biologists.

Tony Stone Photo Library, London



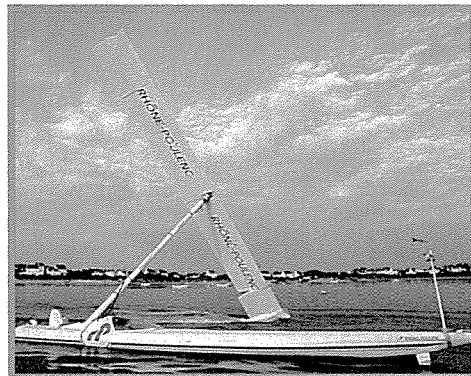
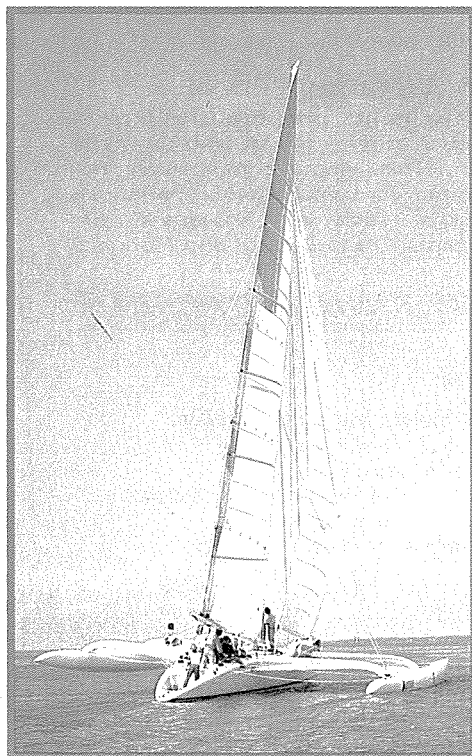
A tandem windsurfer is one of the fastest sailing craft around, providing a large sail area with low weight and little water and air resistance.

This strange craft is the latest in sailing technology, employing a wing rather than the more conventional sail to capture the aerodynamic force normally used to drive a sailing vessel.



John Lythgoe/Planet Earth Pictures

A racing trimaran is able to carry an extremely high area of sail without capsizing due to the support provided by the balancing outrigger hulls.



Philip Plisson/Allsport

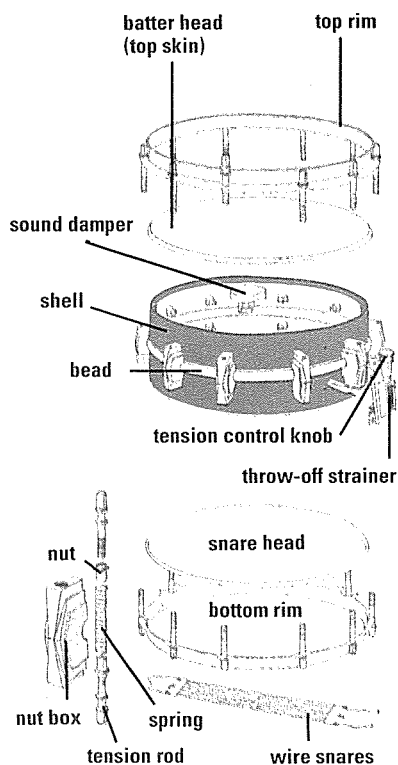
Jet skis, normally powered by 650 cc motorcycle engines, are capable of speeds up to 70 km/h and are steered like a motorcycle.

Gamma/Frank Spooner Pictures



MAKING MUSIC

THE SNARE DRUM



The snare drum is more sophisticated than it looks. A system of rods and nuts (shown, left) is used to adjust the drum's tension, thus changing the drum's tone. The wire snares produce a distinctive 'rattle'.

MUSIC IS HEARD ALL AROUND the world. It is played for relaxation, for dancing – and even for marching. We know music when we hear it: the sound of a door slamming isn't music, but a record on the radio or a concert – these are music.

Music is a series of sounds arranged in such a way that people – or some people, at least – enjoy them. Musical sounds are usually notes. The difference between notes and noises is that the sound

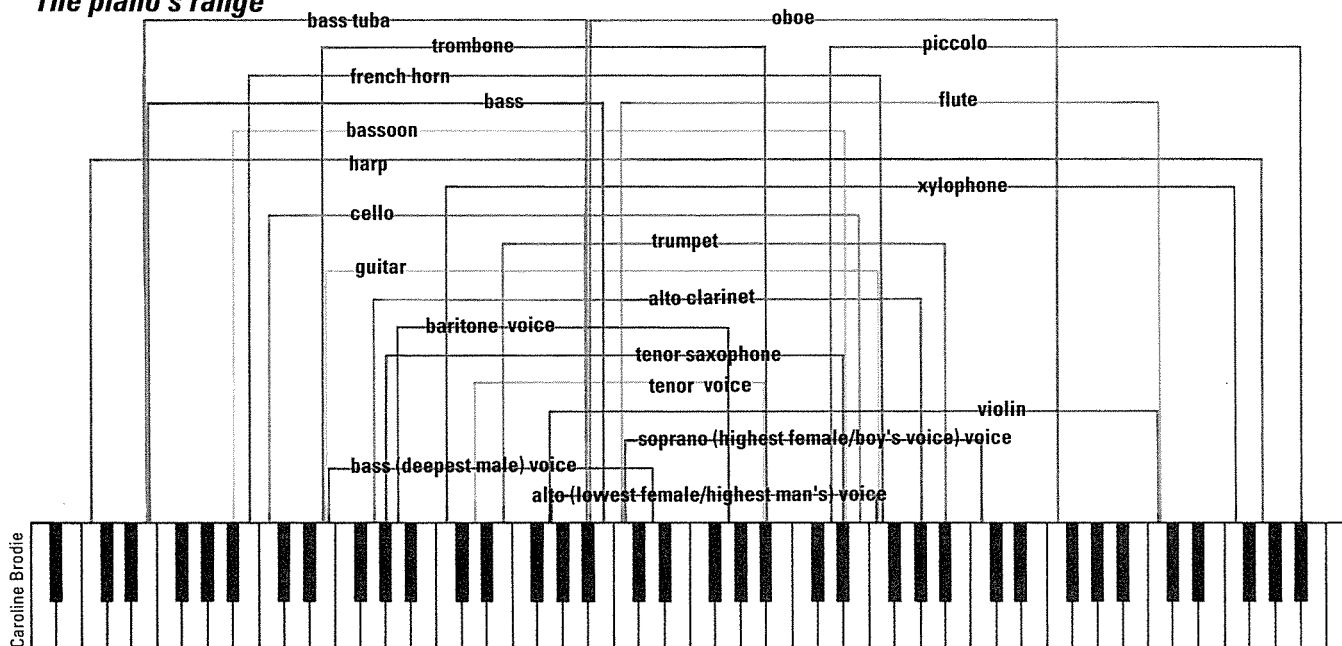
A standard drum kit has snare drums, bass drums, kettle drums and cymbals, all of which make different sounds.

waves forming notes are regular and repetitive, while those making a noise are not. Any series of notes that we like we can call music. Usually we can recognise and remember it; you can whistle a tune, but you can't whistle a door shutting.

You can make music in many different ways. Some instruments



The piano's range



The 88 keys of a standard piano cover the whole musical range, from deeper than a double bass to higher than a piccolo. The human voice falls in the middle.

have strings which are plucked, like a guitar, and others have strings which are stroked with a bow, like a violin. You play wind instruments, such as flutes, trumpets and saxophones, by blowing into them, and you play percussion instruments, such as xylophones and drums, by hitting them.

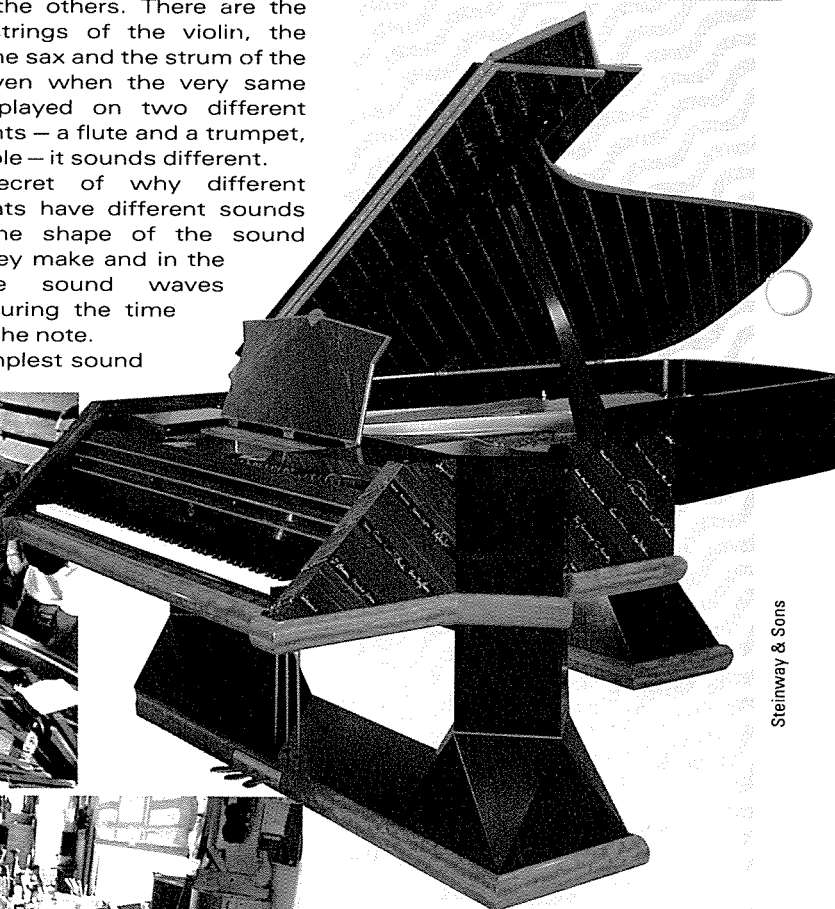
All instruments have their own

special sound, which is different from all the others. There are the zinging strings of the violin, the honk of the sax and the strum of the guitar. Even when the very same note is played on two different instruments — a flute and a trumpet, for example — it sounds different.

The secret of why different instruments have different sounds lies in the shape of the sound waves they make and in the way the sound waves change during the time you hear the note.

The simplest sound

GRAND PIANOS



Steinway & Sons

Grand pianos need a massive cast iron frame to withstand the pounding they get. The tone comes from the wooden case that fits closely around its frame. The keys and the hammers (right) are made separately, and they are only installed once the case is finished.



Steinway & Sons

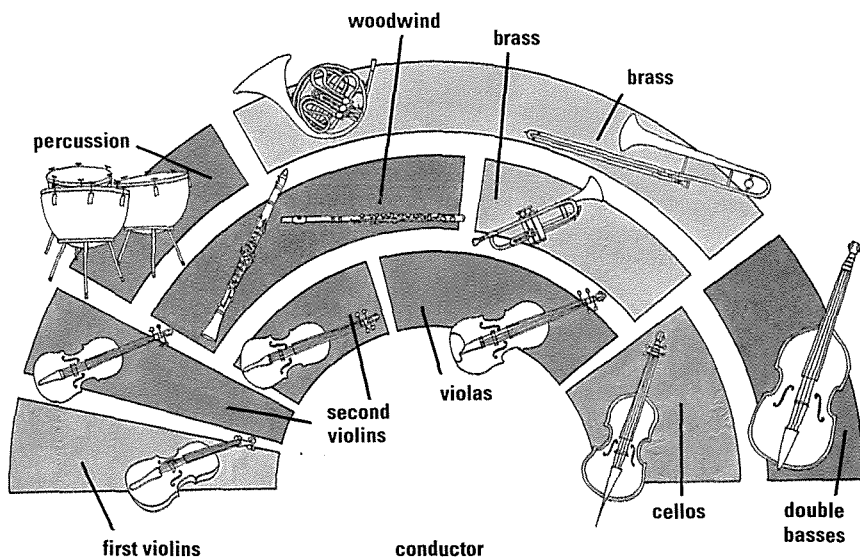
The best known piano makers are Bechstein, Yamaha and Steinway. Steinway recently made its 500,000th piano (above) which has the signatures of the world's most famous pianists inlaid into the wooden case. Eighty percent of a Steinway grand is hand made — the most difficult part being the curved side panels, which are made from 22 layers of wood. Six men are needed and they have only 20 minutes to finish before the glue sets.



— a pure tone — has a sound wave which is very even in shape and is known as a sine wave. This is what is produced by the Greenwich Time Signal (the pips) or a tuning fork. But the sound waves of musical instruments are not single sine waves — they are a combination of many different sine waves. The sound wave of a flute, for example, is quite different to that of a clarinet or a violin.

Harmonics

What makes these waves complex, and not simple, is their harmonics. Whenever you play a note on a musical instrument, many other notes are made at the same time. They are called harmonics and although they cannot be heard separately, it is the mixture of them and the note that was originally played — the fundamental — that



Caroline Brodie



ZEFA

Orchestras are usually arranged with the strings at the front and the louder brass and percussion at the back.

Brass instruments are hand made by stretching and shaping the brass tubing with tools called mandrels.

Electric guitars have taken over from violins as the most popular stringed instruments in popular music. While the violin's wooden body amplifies its sound, the electric guitar needs an amplifier to do so.

vibrating in stringed instruments, and columns of air in wind instruments.

Most instruments also have one or more resonators, which enable them to be heard well and give them their character. Solid objects have frequencies at which they naturally vibrate. Tap a glass — the sound you hear is the result of the glass vibrating at its natural frequency.

You can make something vibrate at its natural frequency by

makes up the sound waves. The characteristic sound of a note from a particular instrument is known as its timbre.

Timbre helps you tell apart instruments from the same family, such as two brass instruments. But there is another factor which helps make different families of instruments sound different — the way their notes change with time. A piano note comes in very quickly and gradually fades away. A clarinet, on the other hand, comes in more gradually and can be kept going by the player.

Columns of air

There is a huge variety of instruments in use around the world. Whatever they sound like and however they are played, they all have one thing in common — something vibrates when they are played. All sounds are produced by objects vibrating — and music is no exception. So strings are set

Tony Stone Photo Library, London



Casio Electronics Co Ltd





Violins are precision-made. Slight changes in the position of the bridge under the strings or the soundpost inside the body can make an enormous difference to the sound.

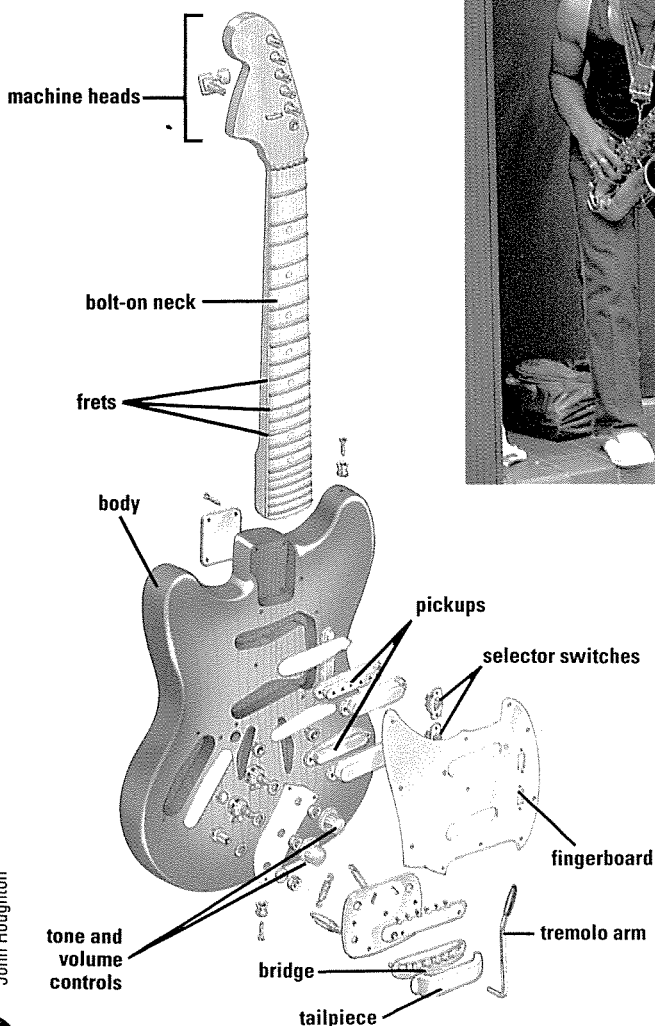
playing that frequency near it; this is called resonance. Musical instruments use the resonance of the materials of which they are made to produce their sound. A violin string vibrating on its own would hardly make a sound, but when it is connected to all the panels that make up the body of the violin, it sets them resonating and you hear the sound of strings.

There are many other stringed instruments besides guitars and violins. The mysterious sound of

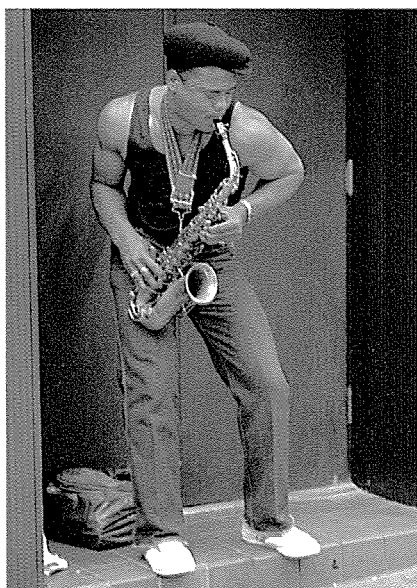
A reed vibrated by the player's breath helps create the sound of many woodwind instruments. The clarinet (right) has a single reed; the bassoon a double reed.



Spectrum Colour Library



John Houghton



ZEFA

Saxophones have a clarinet-style reed and mouthpiece, but a brass body for a brighter sound.

The electric guitar has a solid body and bolt-on neck. The body is fitted with magnetic pickups. These detect the strings' vibrations and convert them to electrical signals. An amplifier amplifies the signals and speakers turn the current back into sound.

make music. Many pop groups and modern composers use synthesizers (see Synthetic Sound, Futures, pages 71-74) that produce the sound waves of other instruments electronically, or make sounds of their own.

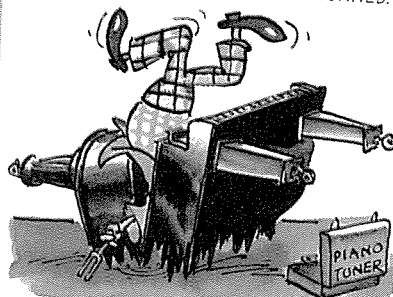
The American composer John Cage has composed a piece called 4'33". For four minutes and 33 seconds, any number of players with any kinds of instruments stand silently on a stage.

The 'music' is just any sounds — such as coughs or sighs — that musicians or audience happen to make, plus any outside sounds.

Just amazing!

HIGHLY STRUNG

WOODEN-FRAMED PIANOS HAVE BEEN KNOWN TO SNAP IN HALF WHILE BEING TUNED BECAUSE WHEN FULLY TIGHTENED, THE PULL OF ALL 88 STRINGS AMOUNTS TO SOMETHING LIKE 20 TONNES.



Paul Raymonde

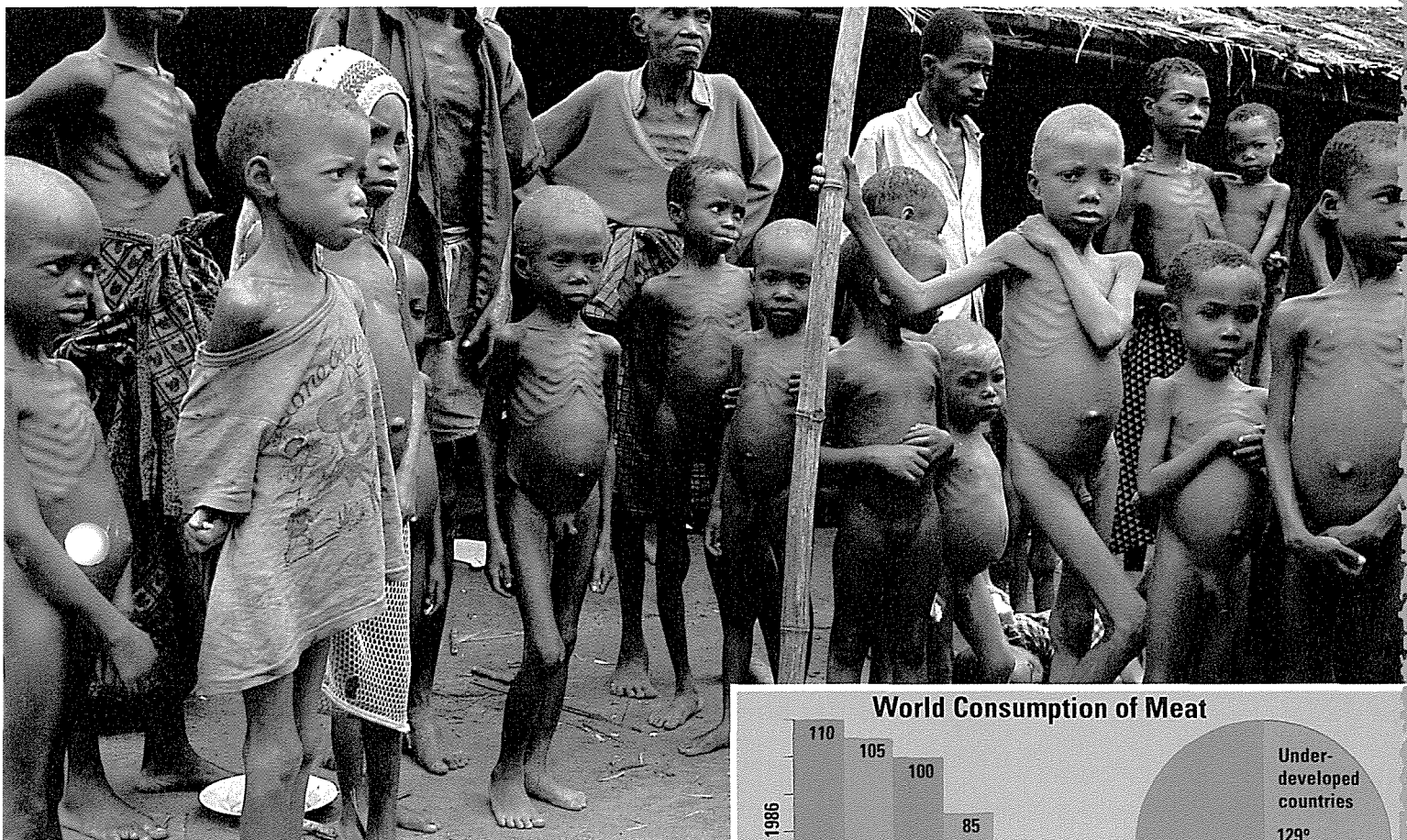
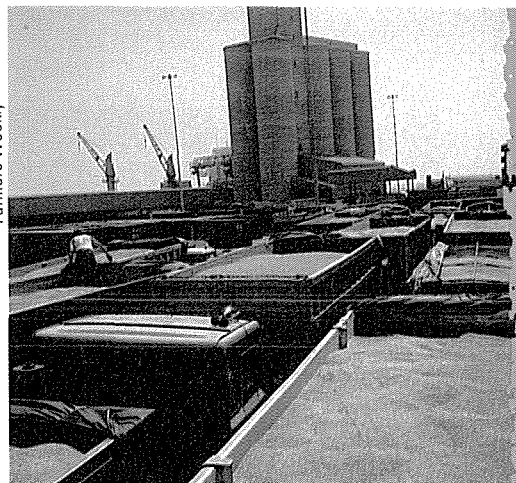


FOOD AID

Farmers Weekly

-  THE RIGHT TOOLS
-  CASH CROPS
-  THE GREEN REVOLUTION

Grain waiting on the docks. Shipping costs prevent European grain mountains being sent to famine areas.



Stuart Heydinger/Telegraph Colour Library

PLANET EARTH GROWS enough food to feed all the people living on it. Agriculturalists have estimated that, if today's foods were distributed evenly, everyone in the world would have enough to eat. In fact there could be enough left to feed several hundred million extra people. Yet millions starve.

Two thirds of the world's population lives in a state of permanent hunger. It takes little to tip the balance into mass death, by starvation, and disease, by malnutrition. Tragically, many of the poorer countries are likely to suffer war, drought or flood — occurrences that can so easily lead to famine and mass starvation.

At first sight, the solution appears simple. Intensive farming in Europe and North America is producing far too much food for the

Developing nations eat a much larger slice of the 'meat pie' than the Third World, which has three times as many people. The largest consumers are the Americans with 800 kg a year each. Some Africans only eat 22 kg.

people who live there. Yet in Africa, parts of Asia and South America, people are dying every day from lack of food. Why can't the developed nations' food surpluses feed them?

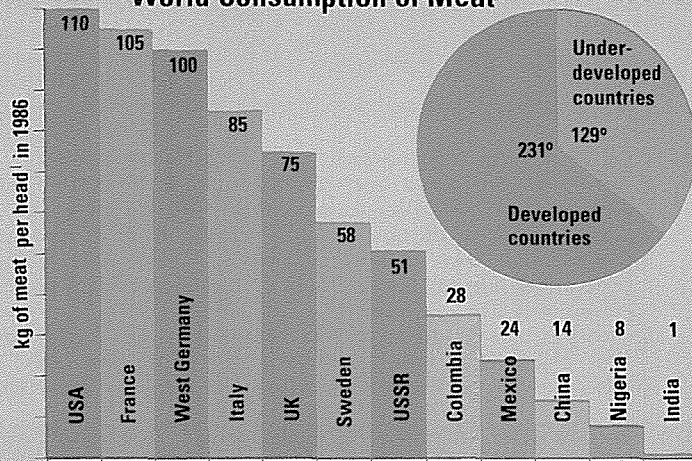
In 1988, the European Community spent about £16 billion, almost two-thirds of its money, on agriculture. Most went on buying up and storing surplus crops and animal

produce. Otherwise European farmers could not sell their products profitably and thousands would go out of business.

Another reason why surpluses are often necessary is the perilously thin line between a large reserve and a potential shortage. Britain's 1.7 million tonnes of surplus grain would only last a few months, if the next harvest failed.

Caroline Brodie

World Consumption of Meat



A GENTLE GIANT

Camels tread daintily, in spite of their size and cumbersome appearance. Their feet, with two toes joined by a web of skin, were designed by nature for walking on soft sand. Equally, they can walk over newly-planted crops without damaging tender young plants. Cattle, on the other hand would wreak havoc and also damage the ground with their sharp cloven hooves. The camel population in African countries is, therefore, being encouraged to grow.

One reason is that the food industries, including the giant bakeries, are geared to a year-round supply. There can be no 'slack season', with huge ovens costing millions of pounds lying idle.

Sending extra food to countries where it is needed also invites many problems. A grain-carrying cargo ship costs thousands of pounds a day to operate. Once the ship

little spare cash to pay for importing extra food supplies.

A share-out of world food appears economically impossible; however attempts have been made to encourage Third World countries to grow more of their own food.

The 'Green Revolution' of about 40 years ago was an attempt by farmers in Europe and North America to breed higher-yielding and more disease-resistant strains of cereals such as wheat, maize and rice. These strains were then grown in parts of Asia and South America.

The results were spectacular: India, for example, grew about 50 million tonnes of cereals and similar

ruined the soil. At the same time, world markets in cash crops became depressed. Hunger spread and the richer countries that had once bought the peanuts and cotton were asked for aid instead.

Hard lesson

Underdeveloped countries' poorer farmers, therefore, have since learned to understand their own needs. The key phrase is 'appropriate technology'. For example, it is no use selling a combine harvester to a poor farmer who has neither the money, nor knowledge to operate it.

The farmers have little money to

Surplus oranges

are used as cattle feed in California.

Elsewhere in the developed world, food surpluses are stored, left to rot, or are deliberately destroyed.

Threshing rice into a basket in northern Thailand. In developing countries, traditional harvesting techniques may be more appropriate than modern methods.

basic food crops in the early 1960s. By 1970, this had doubled, while the country's food imports had fallen by half.

Bitter harvest

But success was short-lived. As the price of oil leapt in the 1970s so the cost of vital fertilizers soared out of reach of most of the poorer farmers. Production levelled off – in some places it fell.

Vast areas of the Sahel region in central west Africa, for example, were at one time used for growing peanuts, cotton and other cash crops (a cash crop is one grown purely for money to buy food and fuel for the farmer and his family). Soil erosion, plant diseases and highly intensive farming gradually

buy and run machines and their farms are far too small to make efficient use of them. The hand-operated rice transplanter, on the other hand, was especially developed for the small farmer and was one of the successes of the Green Revolution.

Now the search is on for plant crops that small farmers can grow using simple machinery.

reaches its destination, the food must be unloaded and distributed. Again, someone has to pay. Countries that produce excess food might feel that selling off stocks cut-price could be possible, but financing its transport half way around the world is too expensive. To compound the problem, the countries where famine is rife have

F Botts/FAO

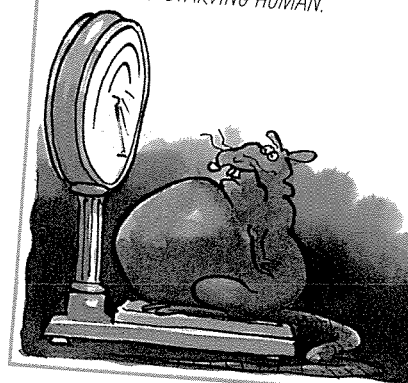
Nigel Cattlin/Holt Studios Ltd

Peter Menzel

Just amazing!

FOOD FOR THOUGHT

EVERY YEAR, THE WORLD'S RATS AND MICE EAT OVER 40 MILLION TONNES OF FOODSTUFFS – MORE THAN ENOUGH TO FEED EVERY STARVING HUMAN.



Paul Raymonde

A camel's head hangs in a Tunisian butcher's shop. After finishing its useful life as a beast of burden, the camel is often killed for meat.



IRRIGATION

HARVESTING RAIN

SELECTIVE PLANTING

DESERTS ARE GROWING — year by year vast areas of the world, particularly in Africa, are made less productive through greed, ignorance or poor farming techniques.

Taking water to dry areas is one of the most basic ways of increasing food productivity so that crops grow better, or plants that would otherwise not grow can be raised. But different situations demand different solutions. Centre pivot irrigators are one high-tech answer for large-scale farming. An immense snake-like arm, up to nearly 1 km long, circles round a central tower, spraying water from hundreds of nozzles. The arm is divided into

sections, which run on wheeled bogies. Each bogie is driven by an electric motor, with the speed adjusted automatically to keep the arm straight. Pesticides or fertilizer can be added to the water as and when they are needed.

The biggest system is in South Africa, with 33 sections and covering more than 1,000 acres in a single gigantic revolution.

Low-pressure systems

Such hugely expensive machines are beyond the reach of farmers in poor countries. More appropriate are various kinds of low-pressure irrigation systems. In drip-feed or trickle irrigation, narrow plastic tubes snake across the fields. They carry water slowly but frequently, keeping the soil moisture topped up.

By contrast, a tiny state like Israel (which is roughly the size of Wales)

has coped with a barren, stony terrain and low rainfall and literally 'made the desert bloom'. The answer is in technology and research.

Ancient secret

Archaeologists have found that in pre-Christian times the stony Negev desert was farmed and several cities flourished there. The ancient secret was a system of hydraulic engineering now known as run-off agriculture. It consists of harvesting rainwater from high ground and concentrating it on small terraced fields below.

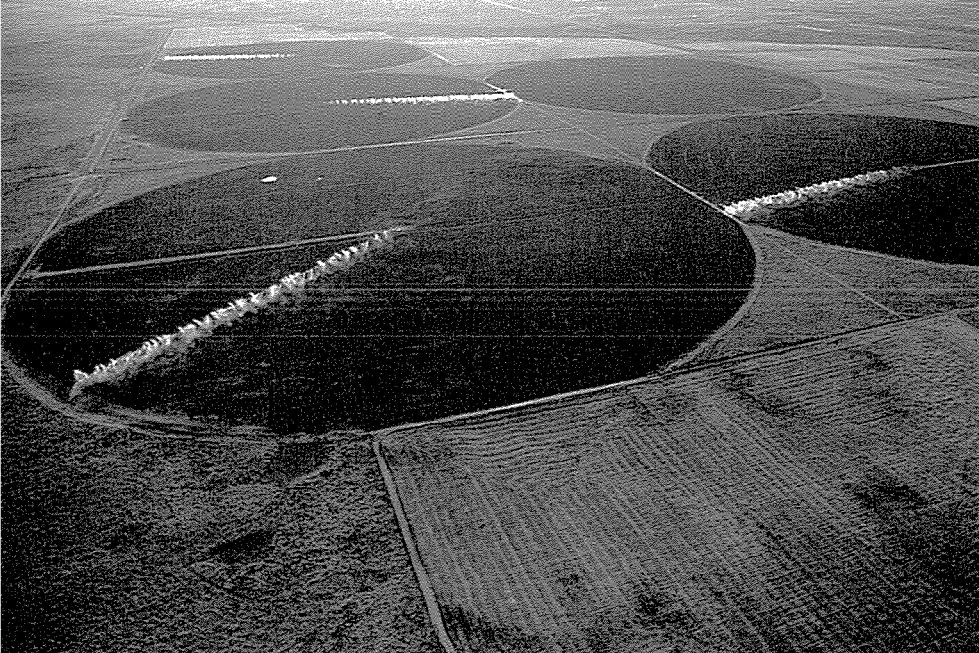
Harvesting dew

Israeli scientists are also researching techniques for obtaining water from the air by dew-trapping devices, and from the sea by desalination (removing the salt).

In Kenya, the Baringo Fuel and

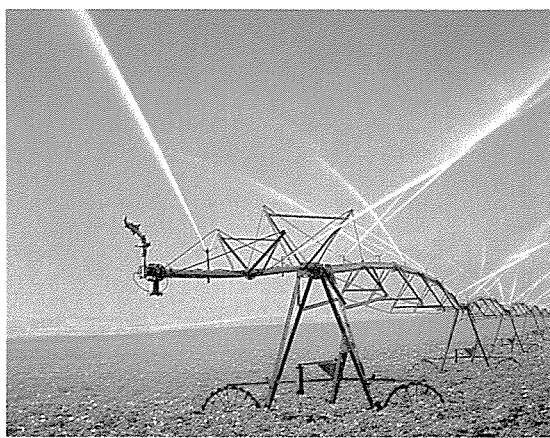
A desert oasis, Morocco, the lush green contrasts sharply with the miles of barren land surrounding it.





Grasses were planted among the trees, and cut regularly as fodder for cattle, sheep and goats. But unfortunately, farm animals, as well as wild ones from the surrounding bush, were attracted to the fields of saplings and young grass. Wood was too valuable to build fences around all the fields. The answer came in the shape of solar-powered

ZEFA



American potatoes can be grown in the desert thanks to this huge mechanical sprinkler. The irrigation system can be operated from kilometers away by remote control.



Israel's Negev desert has plentiful sunlight and can now support crops with a simple watering system.

electric fences. These deterred the animals by giving them a mild electric shock whenever they made contact with the wire. Once bought, the fences ran on the abundant sunshine and kept the marauding animals out.

Future hope

The Baringo project has been successful – so far. It truly came from the grass roots and hopefully could be an example to others.

Fodder Project has shown on a small scale how the future can be tackled successfully.

About 100 years ago, the Baringo area was cloaked in dense, lush grass as tall as a man. Then European farmers moved in and their dense herds of cattle grazed the goodness out of the soil. The local scrubby bushes were turned into charcoal, for fuel in big cities like Nairobi. The soil was bare, and stony, useless for agriculture.

Rehabilitation

Rain does fall in the region, about 600 millimetres each year. But it is concentrated in short showers too heavy for the ground to absorb. The water mostly runs away in deep gulleys, washing off the nutrients in the topsoil as it goes. So the workers dug a criss-cross system of embankments, following the contours of the field. Next time it rained, each rectangle held the water like a miniature shallow pond. Into these rectangles, grasses and a few young trees were planted.

Centre pivot irrigation, USA. The Navajo project collects water from the Colorado river basin and uses it to grow crops in the surrounding desert.

PLANTS WITH A FUTURE

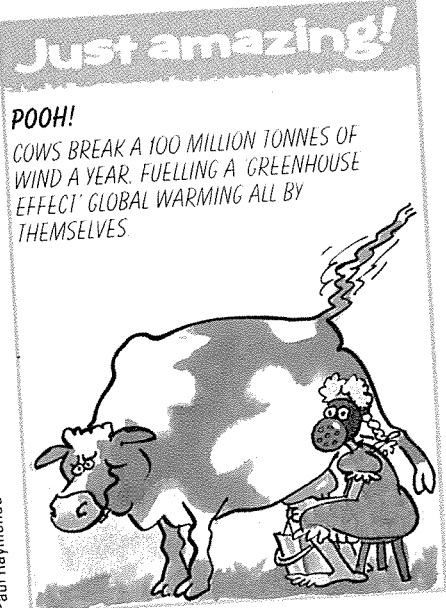
Among the many plants offering new solutions to the problems of growing crops in harsh lands are:

- The Somali Yeheb bush: a native of arid lands, it has nutritious peanut-sized seeds
- The hairy wild potato: a wild plant whose pest-deterrent scent could be bred into other crops
- Spirulina: a tiny protein-rich alga that flourishes in the salt lakes of arid lands
- Pomelo: similar to a grapefruit but can weigh up to 10 kg; it is very rich in Vitamin C
- The winged bean: every part of this plant is edible. It promises to become the 'soyabean of the tropics'.

The Baringo people decided to concentrate on producing wood for cooking fires, plant crops for themselves, and fodder for their animals, rather than cash crops.

Productive plants

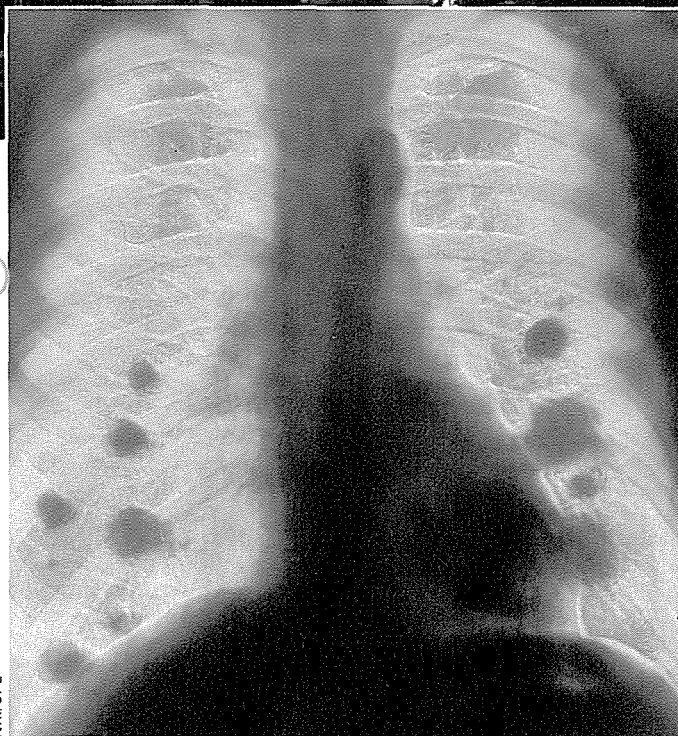
Various kinds of trees and grasses which could grow well in their dry climate were carefully examined. Prosopis trees from South America have been successful. Their wood is hard, for fences and building, and burns well. Their leaves and pods are fed to farm animals. A local African species of acacia also grows well in the region. It enriches the soil and its pods of beans are eaten by livestock. Another local species, the shrub *Berchomia*, produces hard wood and good charcoal, and sweet fruits for animals and people. The desert date produces leaves eaten as a vegetable, and seeds ground into flour or crushed for oil.



POOH!
COWS BREAK A 100 MILLION TONNES OF WIND A YEAR. FUELLING A 'GREENHOUSE EFFECT' GLOBAL WARMING ALL BY THEMSELVES

Paul Raymonde

Pollutants from a steel works often include large amounts of nitrogen and sulphur gases, as well as particles that can cause lung cancer (orange spots on X-ray, inset below left).



HEALTH WATCH

Fred Maroon/SPL

CNRI/SPL



HEALTH HAZARDS

THE HUMAN BODY IS WELL equipped to survive in our world of pests and diseases, accidents and extremes – from temperature to stress. How well we cope with these factors depends on how much care we take over hygiene and nutrition – the two keystones of good health.

Personal hygiene means keeping the body clean, which mainly involves caring for the skin. Our skin is a very complex structure. The biggest and one of the most important organs of the body, it accounts for 7–20 per cent of the body's



POLLUTION

weight. The average 75 kg man has 5–15 kg of skin.

Most of the skin's functions we take for granted and do not notice, but healthy skin is essential to well being. We can live with one kidney or even one lung, but if one-third of our skin is damaged (for example by burns) our life is seriously at risk.

To keep our skin healthy it must be treated with care. The skin is protected by natural oils. If the skin is de-greased too well – by using too strong a soap, for instance – it will dry out and become flaky; also, certain bacteria may take advantage and cause problems or illnesses.



LIFE EXPECTANCY

The skin must be kept clean, but using too much soap will disturb its chemical balance. Careful washing is usually all that is needed to keep it healthy.



Nutrition

The teeth must be brushed regularly to prevent the build up of plaque – a hard coating of saliva, food particles and bacteria. If plaque builds up on the teeth, acid produced as the waste product of bacteria can cause gum disease and tooth decay.

Many diseases are caused by bad eating habits. It has been proved





Blotches and rashes can be caused by bacterial infection, but soap and make-up or even what you eat can have similar effects.

SICK BUILDING SYNDROME

Chemicals given off by materials in modern buildings can cause illness in some people. Symptoms vary from headaches and drowsiness to lethargy and runny eyes.

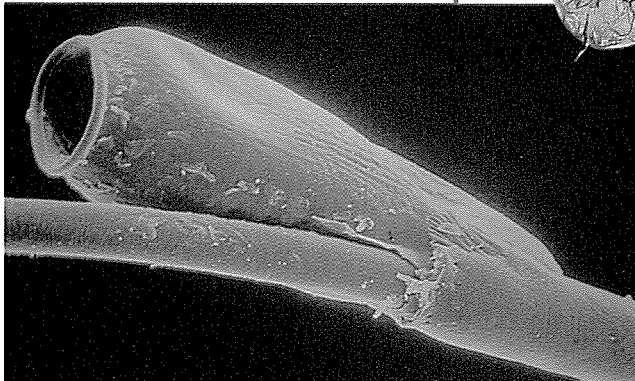
These buildings are not factories and laboratories, where you might expect to find pollutants – they are offices. The materials used in offices appear harmless, but a bottle of typewriter correcting fluid, for example, contains chemicals that evaporate when the fluid is used. Pens, typewriter ribbons and adhesives all release chemicals, many of which are toxic.

The problem is even more acute when the materials that make up the structure of the building is considered. Wall coverings, insulation, even carpets are all sources of pollution. Harmful substances given off include formaldehyde from chipboard, benzene from inks and cleaning solutions, toluene from rubbers and ozone from photocopying machines. In addition, there are often fungi, bacteria, cigarette smoke and dust in the atmosphere.

In well-ventilated buildings, these substances do not build up to noticeable levels, but modern, air-conditioned buildings have sealed windows, and their ventilation systems do not always purify the air they circulate. The result is a stale, toxic atmosphere which can make some people feel ill. This problem is one of the reasons large numbers of people go absent from work each year.

the flow of blood. A partly blocked section of the vessel can be cut out and the vessel rejoined.

The important word in any diet is balance. You need fats (and cholesterol) for normal health, but too much causes disease. This is true for everything you eat – too much causes one problem in the same way that too little causes another. A good balanced diet containing vegetables, fruits, cereals and meat contains all the protein, fat, carbohydrate, vitamins, miner-



Cath Wadforth/SPL

The head louse lives in human hair – it especially likes clean hair – and feeds on human blood. It 'glues' its eggs, or nits, (left) to the hair.

SPL

als, and roughage needed for health.

What you do to your food in the kitchen can make all the difference between a healthy meal and a poor one. A potato, for example, is healthy when baked in its skin – less so if made into chips and fried.

Some diseases may be controlled

The smoke from cigarettes contains tar and nicotine. The tar blocks up the small airways in the lungs and irritates the delicate membranes lining them.



Nicotine addiction

Nicotine (a drug found in tobacco) acts on the central nervous system, making the smoker dependent on the drug. The tar and accompanying irritation of cigarette smoke cause a change in a cell's structure, which helps to turn it into a cancer cell. This altered cell divides at an abnormal rate to produce a tumour mass – lung cancer.

Some cancers seem to be more common in certain areas of the



SPL

that a diet high in fats and sugars increases the chances of people developing arteriosclerosis – a narrowing of the arteries (vessels that carry blood from the heart). Cholesterol (a substance found in all animal fats), is deposited on the walls of the blood vessels where it builds up, causing them to narrow. The effect is to reduce or even stop



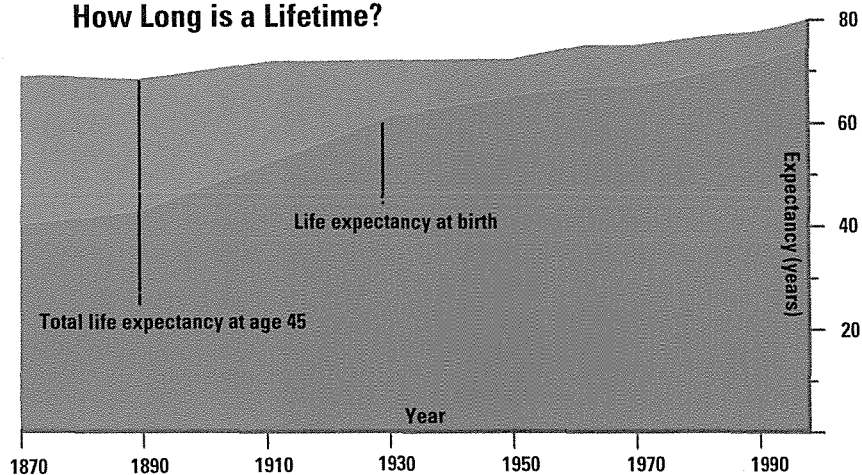
SPL

Bacteria (red), magnified 1800 times, feeding on plaque on the surface of a human tooth (yellow). Plaque contains food particles trapped in saliva. Frequent brushing prevents its build-up, but on neglected teeth it hardens and must be scraped off. A dye or discloser shows plaque as dark areas on teeth (above left).



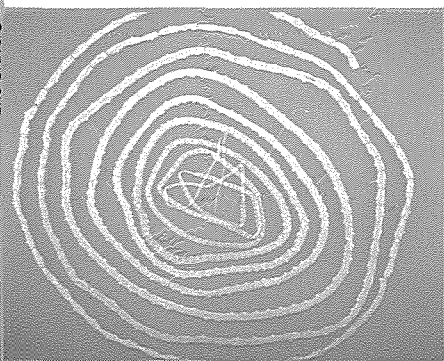
Life expectancy in the developed world has risen – not because of advances in medicine, but because our diet is healthier and the environment is cleaner.

How Long is a Lifetime?



Eric Graves

CNRI/SPL



The tapeworm parasite lives in the intestine, causing increased appetite, weight loss and weakness. In humans, it can grow to 10 metres long (inset above).

Arc welding exposes a worker to many hazards, including electric shock, burns and lung cancer (from inhaling harmful fumes).

phere with the exhaust gases. But it is poisonous, especially to children, harming the brain.

Freezing cold

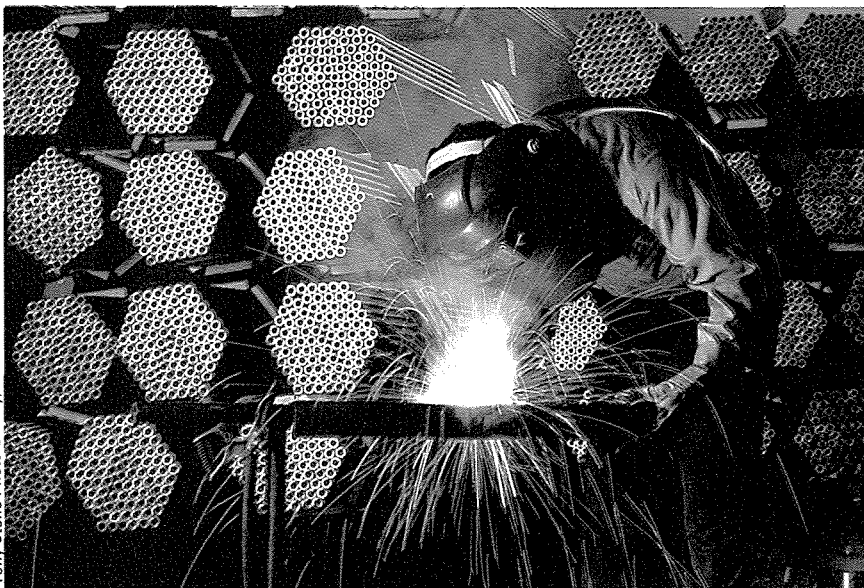
In countries that have cold, damp winters, old people may die from hypothermia (the body gets too cold to work correctly) or from respiratory diseases, such as bronchitis and pneumonia.

We all have adaptations to live in our own environment. That is why people who live in cool climates but holiday in warm countries may burn in the sun. During heat waves, many people suffer dehydration, because their bodies are not used to extreme changes in the weather.

Caroline Brodie

world. For example, in Japan, stomach cancers account for more than half the deaths from cancer. The reason for this is not clear, but it appears to be linked to diet. Yet in Japanese people living in, say, the USA, the cancer rate is between that in Japan and that in the USA. So the environment seems to be a factor that affects the chances of getting cancer – but just how is not yet understood.

The environment has a large influ-

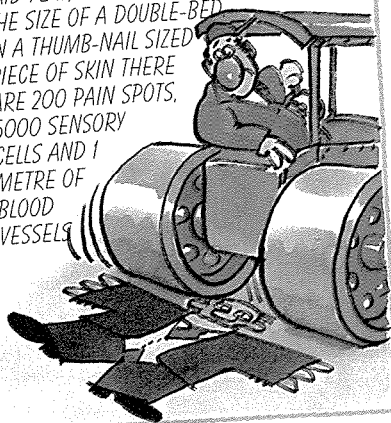


Tony Stone Photo Library, London

Just amazing!

SKIN DEEP

IF THE SKIN OF AN AVERAGE ADULT WERE LAID FLAT, IT WOULD COVER AN AREA ABOUT THE SIZE OF A DOUBLE-BED. IN A THUMB-NAIL SIZED PIECE OF SKIN THERE ARE 200 PAIN SPOTS, 5000 SENSORY CELLS AND 1 METRE OF BLOOD VESSELS.



Paul Raymonde

ence on the health of a population. In tropical countries, insects and bacteria thrive in the hot weather. Many of them either cause disease or spread it. Together with poor hygiene and a lack of clean drinking water, they are a major health hazard.

In the developed world, where the spread of disease is much less of a problem, there is a greater threat from pollution. For instance, lead is added to petrol for smooth engine running and high performance and passes into the atmos-

Some work environments can be bad for health. Miners, as well as workers in dusty factories, may develop respiratory diseases. Noise pollution from heavy machinery can damage the unguarded ears, and certain chemicals used in industry can cause skin cancer.

Many old buildings contain asbestos as a fire-proofing material. Only after some workers fell ill with asbestosis – a respiratory disease – did the harmful effects of this material become known. (Asbestos is still used in some countries in build-





A red cast over California at dawn – the effect of light being scattered by dust particles, air molecules and water droplets in the atmosphere. Large particles of pollution, or even large water droplets, can reduce the amount of blue light reaching the ground, so the sky appears yellow or even deep red.

Tony Stone Photo Library, London

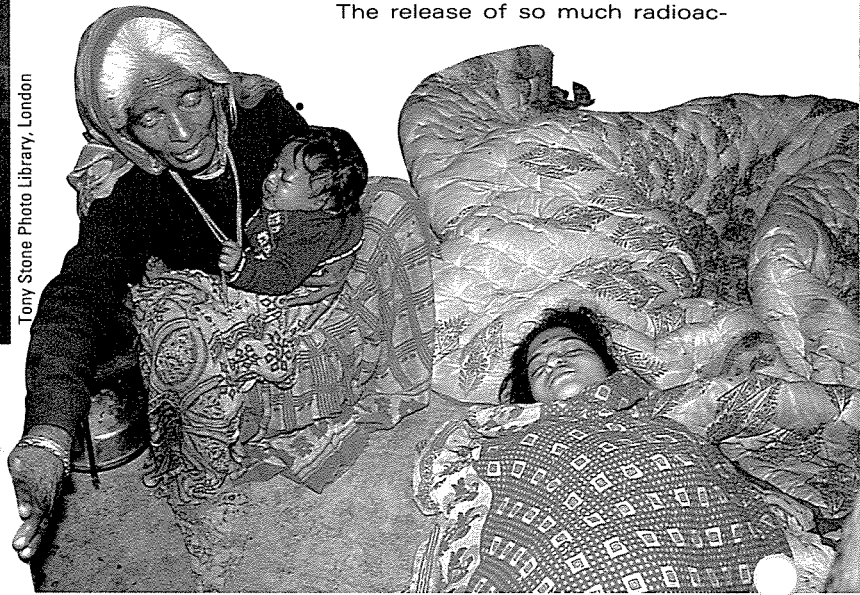
have been blinded and more are suffering from kidney failure.

A disaster of even larger scale was narrowly averted after a nuclear meltdown in 1979 at Three Mile Island in the USA. If this had not been contained, the entire populations of New York, Boston and Washington could have been killed.

Excess radioactivity

Accidents such as the Chernobyl disaster of 1986 in the Soviet Union – labelled the world's worst nuclear disaster – add more pollutants to the already polluted atmosphere.

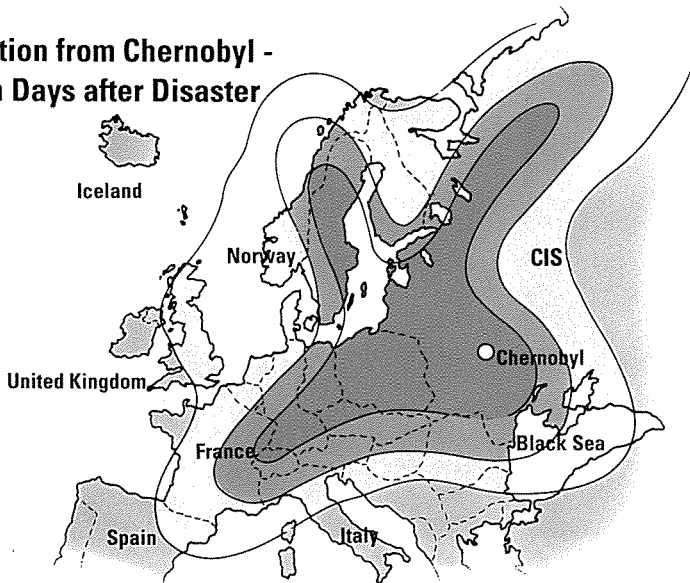
The release of so much radioac-



Radioactive debris thrown up into the atmosphere after the Chernobyl disaster was carried huge distances by the wind – raining down on countries as far away as Britain and Sweden. (The heaviest concentration is the dark brown area on the map.)

Victims of Bhopal were blinded by the toxic gas that escaped from the chemical plant. Some suffered kidney damage.

Radiation from Chernobyl - Seven Days after Disaster

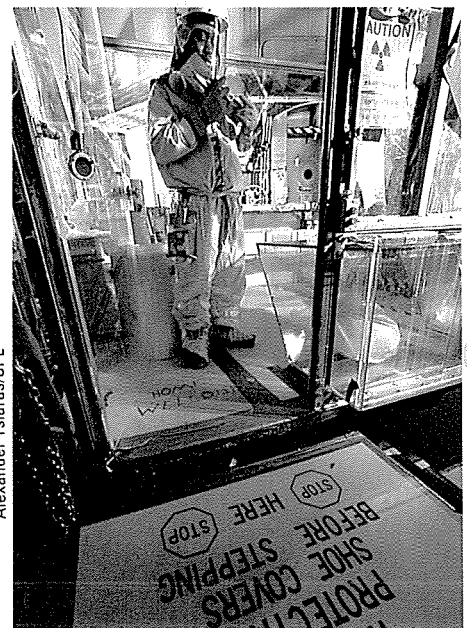


Chris Lyon

tive material into the skies affects both human and animal populations. A farm more than 50 km away from the reactor reported that, during the first nine months following the accident, 41 out of 87 pigs and 63 out of 350 cows were born with abnormalities. Some lacked heads, limbs, eyes and ribs; others had deformed skulls.

Gamma/Frank Spooner Pictures

Radioactive contamination at the nuclear plant at Three Mile Island is expected to take 40 years to clean up and make safe.



Alexander Tsiras/SPL

ings; it is dangerous only when it breaks down and the fibres escape into the atmosphere.)

Pollution can threaten the lives of large numbers of people over wide areas. Large-scale evacuations were ordered by the Italian police in the neighbourhood of Seveso near Milan in July 1976 due to an accident at a chemical plant that released a small quantity of a weedkiller called TCDD into the air. The danger came from a by-product

called Dioxin, which produces a blistering skin rash even in minute doses. Dioxin contamination may take many years to clear.

The appalling loss of life that can result from industrial pollution was made clear in the Indian city of Bhopal in December 1984. A leak of foul-smelling methyl isocyanate gas from a storage tank at a Union Carbide Chemical factory killed at least 2,000 people. The gas has affected a further 200,000 – many



GLOBAL VILLAGE

- SUBVERSIVE VIRUSES
- COMPUTER VANDALS
- NETWORKS

ON THE EVENING OF 2 November 1988, thousands of computers ground to a halt across America. Internet, one of the world's largest computer networks, had been attacked by a computer 'virus'.

A virus is a sophisticated program that reproduces itself within the computer's own system, and spread from one computer to another with alarming speed. By the time this one had been destroyed, 36 hours later, the bill in computer 'downtime' (the time the system was out of action) had climbed to \$100 million.



Growing concern

Happily this particular virus, planted by a student, was not intended to cause any lasting harm and did not eat up data. But it highlighted mounting concern about the security of giant computer networks around the world.

As more and more computers are linked together in what has been called the 'electronic village', the danger of attack grows. And it is not only programs like viruses that pose a threat. With secret defence plans and confidential information about companies and individuals routinely held on computer files, the risk of secret data being stolen is mounting.

Ellen Schuster/The Image Bank



Village voices

Two big technical breakthroughs made the electronic village possible. The first was the development of the modern phone system, which made high-speed communication possible between almost any two points on the Earth's surface. The second was the arrival of cheap, powerful, personal computers.

The ordinary phone system relays its electrical messages around the world by electric cable, fibre optics, radio waves and mirror waves relayed by orbiting satellites. It can also carry data between computers.

This means that almost any home computer can be connected via the phone line — using a modem (short for modulator-demodulator) — to a global communications network and hundreds of thousands of other computers — home computers, desktops and huge mainframes.

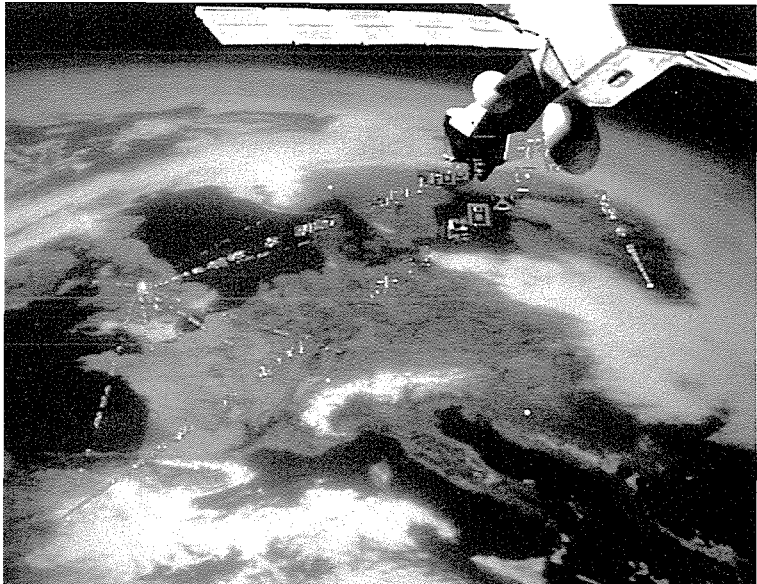
The on-going installation of fibre-optic cable instead of ordinary copper ones in phone systems is accelerating the growth of these global communications. Fibre-optic cables are able to handle vastly more communications 'traffic' than copper ones of the same size: they can carry

The world has shrunk, electronically. Using a normal phone line and a computer, you can obtain information from huge, remote data bases on any subject — in seconds.

an astonishing 30 million characters — or the entire contents of a large encyclopedia — every second!

In the future every home and office will be linked into a fibre-optic communications network, in which large computers will act as exchanges, automatically directing messages at high speed to their





Satellites hover in the sky relaying phone conversations, computer data and fax signals. If you want to send money from England to Australia, it travels this way too. Billions of pounds are exchanged between banks by this method every hour of the day.

discuss plans, share ideas and attend meetings without ever stepping outside their front door. This will have a dramatic effect on cities – cutting the need for office space, relieving commuter congestion and allowing office workers to move further out into the countryside.

Personal papers

With every home connected to an increasingly powerful information web, our lives will change in other ways. There will be electronic newspapers personalized to each subscriber's taste. If your interests, say, are sport and foreign affairs, the electronic newspaper will scan the major reports coming in on

British Telecom

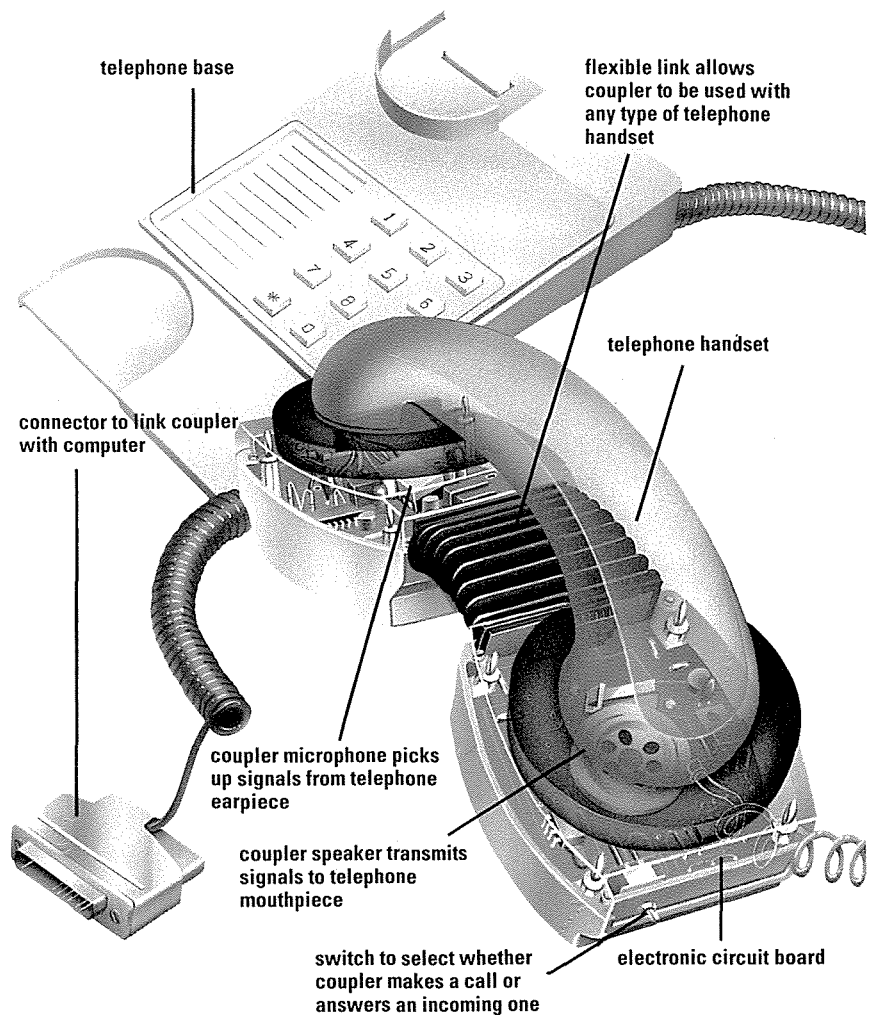
destinations. In this lightning-quick network, two people located anywhere in the world will be able to use their personal computers to exchange text, drawings, photographs and film.

They will even be able to see and hear each other, using miniature TV cameras and colour monitors. All this fantastic range of sound, pictures and computer data will travel simultaneously along the same pathways through the same giant network.

One effect of the electronic village will be to make conventional offices obsolete. Instead of battling through crowds and traffic jams to get to work each day, more and more people will be able to do their work at home.

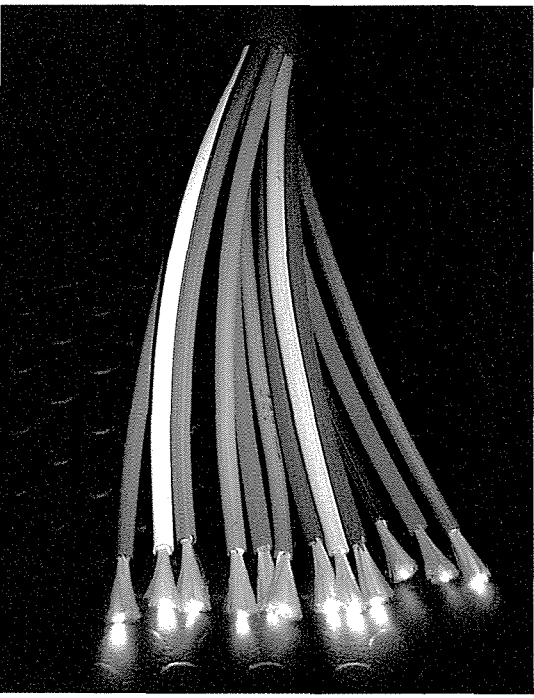
A personal computer, plugged into the worldwide communications network will allow employees to

MODEMS – CONNECTING TO THE WORLD



A modem is a device that sends data from one computer to another down the phone line. All information in a computer is stored as circuits switched on or off, equivalent to series of '0's and '1's. The modem takes these 'ons' and 'offs' and turns them into a series of high and low tones. These are sent down the phone line. At the receiving end, another modem converts these high and low tones back into 'ons' and 'offs'.

The simplest type of modem, known as an acoustic coupler, has rubber cups into which a standard telephone handset can be pressed. A small loudspeaker generates the stream of high and low tones into the mouthpiece, while a small microphone picks up the data stream from the earpiece. Many modems bypass the handset altogether and directly connect to the phone line.



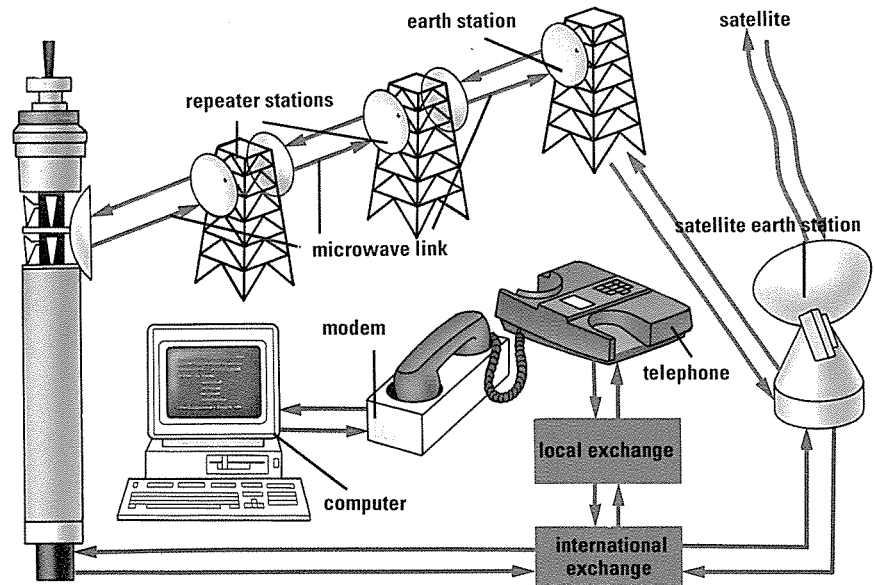
David Parker/SPL

Fibre optics allow even faster communications. Huge amounts of information, travelling at the speed of light, can be carried down slender fibre-optic cables.

Mark Franklin

these topics and then store them in your computer's memory. In the morning — or whenever you want to read your paper — a front page with crystal-clear graphics and colour headlines will pop on to your computer screen with articles on, say, the World Cup finals or kidnapping in the Middle East. To read the terrorist story, say, you just touch the head-

GLOBAL VILLAGE



John Houghton

Your phone connects you to the world. Through microwave satellite links, you can speak to almost anyone on the planet. And if you couple up your computer via a modem, the world's data is yours to tap.

keep track of their accounts. Shops and ticket agents advertise through teletext services that appear on your TV screen.

Some of these services are connected to the phone line and are interactive. Punch in a credit card

called 'Virus' rings telephone numbers at random until it finds another computer. It makes a copy of itself in that new system, then both the parent program and the new copy start dialing again.

Evil geniuses

Today, fiction has become fact as hundreds of viruses invade millions of computers around the world each year. Most are planted by malicious program-

The video phone allows you to see who you are talking to. Ultimately, it will be 3-D, as if the caller were present in your room.

line on the screen and all the details flash up. These may even include a TV interview with one of the hostages shown right alongside the computer text!

Banking, shopping, even attending school classes, can all be done without leaving your home, thanks to the electronic village. Already some banks offer their clients special home terminals where they can

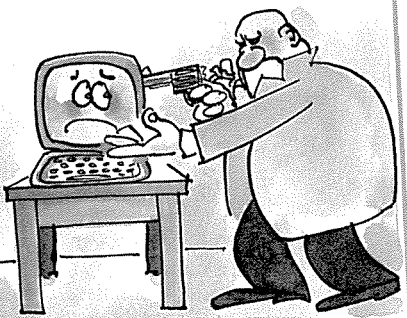


Simon Fraser/SPL

Just amazing!

ON ACCOUNT

STANLEY RIFKIN SWINDLED \$10.2 MILLION — ALL AT ONCE — FROM A LOS ANGELES BANK'S COMPUTER SYSTEM BY GAINING ACCESS TO THE BANK'S TRANSFER SECURITY CODES.



Paul Raymond

number and you can get goods delivered to your door or make a holiday or entertainment booking. And by getting into other huge commercial databases with your personal computer, you can track down information on virtually any subject.

Computer criminals

But all this sharing and availability of electronic knowledge has its dangers. The network is vulnerable to anyone who wants to misuse it — the hackers and the computer criminals.

The idea of a computer virus was first mentioned by David Gerrold in 1972 in his book *When Harlie Was One*, where a computer program

The photophone, like the fax machine, sends pictures down the phone line. The images, though, are finely detailed and computer generated. In medicine, photophones may be used to get a second opinion.

mers, called hackers, who purposely infect networks with viruses just for the fun of it. Usually the viruses only fill up unused storage space, without actually destroying data, though clearing up after them can still lead to extremely expensive delays.

As well as viruses, computers have been attacked by hostile programs known as worms, Trojan horses, and logic bombs! Trojan horses are viruses passed from

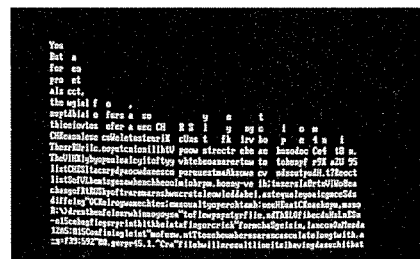
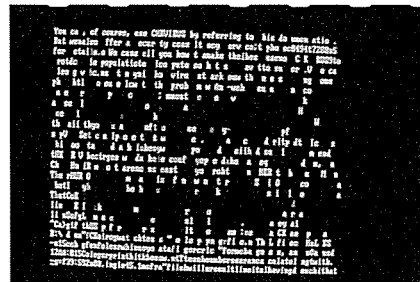
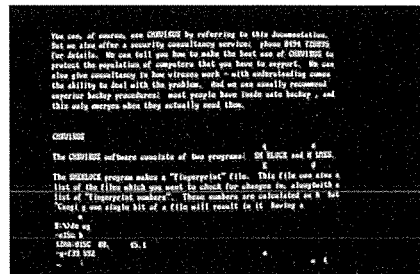


computer to computer, hidden inside a seemingly innocuous program and a logic bomb is a virus that waits for some specific event — Friday the 13th or the hard disc being half full — before it triggers.

Attacks on computers that control weapon systems could be especially dangerous. As a result, the

specialize in making vaccines — special counter-programs that will seek out and destroy future strains of virus!

In Britain, software companies have joined forces with computer users to fight electronic vandalism. Eventually, the new British group, called the Computer Threat Re-



Jerry Mason/New Scientist

Computer viruses have already hit NASA. Imagine the chaos if the computer was attacked during a mission.

United States Department of Defense has set up a Computer Emergency Response Team to guard its top-security networks.

Some companies, like FoundationWare in Cleveland, Ohio, now

search Association, hopes to forge links with similar organizations in Europe and the rest of the world.

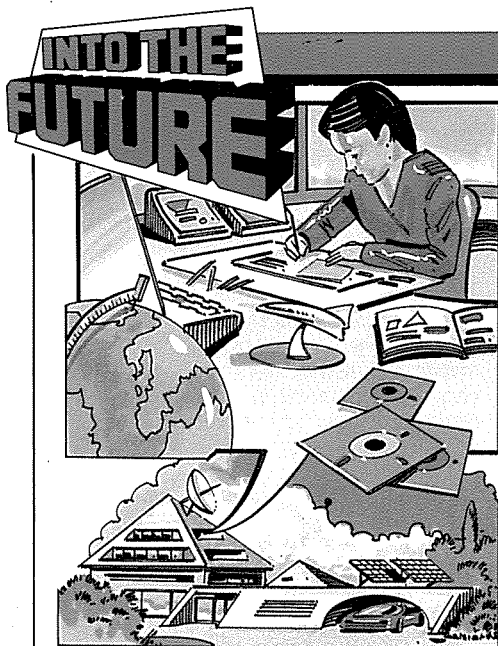
So far there are few countries where hacking has been made illegal. But if the spread of viruses continues, that will inevitably be the result.

Criminals who use computers to divert huge sums of money into their own bank accounts are already breaking the law, no matter how

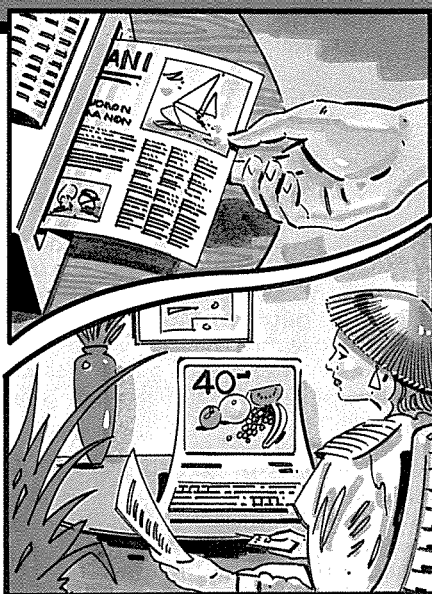
A computer virus in action. This one makes letters fall off the screen, one by one, until they are all in a jumbled heap along the bottom

clever they think they are being.

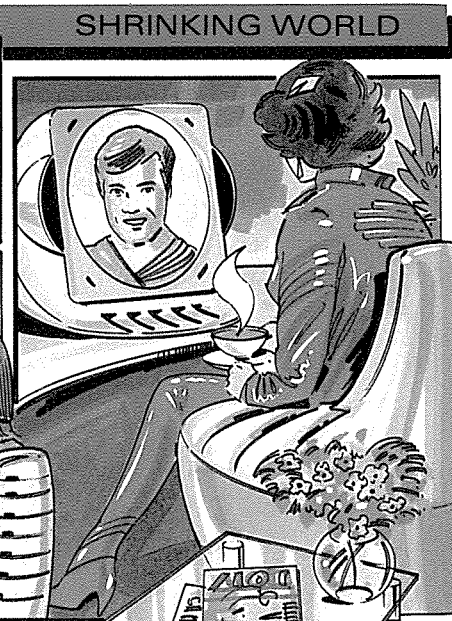
But the worst threat comes from computer spying. There seems to be no foolproof security systems that can protect personal information, commercial data and military intelligence on computer.



▲ Next century, it may be unnecessary to go out of your front door. Children the world over could be taught in a huge electronic classroom via interactive TV.



▲ Mail and newspapers will be delivered electronically. Banking and shopping will be done from home. Voice-print identification will act as a signature.



▲ Videophones will present moving, lifelike, 3-D holographic images, and the telephone will automatically translate for you if the caller speaks a different language.

THE SECURITY OF ITS OWN country's borders is of vital interest to any government. Borders that are not fixed and settled are a major cause of wars. And the flow of arms, drugs, crime and illegal immigrants across international borders is a major cause of internal strife.

Most borders have been in place for hundreds of years. They often follow natural geographic barriers — such as seas, rivers and mountain ranges — and mark a clear cultural or political difference between the people on either side. The French live on one side of the Pyrenees, for example, the Spanish on the other.

Cause of strife

Other borders have come about because of conquest, colonization or political expediency. This has left some countries in dispute over just where one begins and the other ends.

Iran and Iraq fought over the Shatt al-Arab waterway since 1980. And in 1974, some Cypriots of Greek descent wanted the Mediterranean island of Cyprus to become part of Greece, so the Turkish army invaded the northern part of the island to protect — as they saw it — the rights of Cypriots of Turkish origin.

Troubled times

Some Irish feel that Britain has no right to any part of the island of Ireland, while others — largely those in the north of British origin — feel that although many of their ancestors came as settlers in the wake of conquering British armies, they have been there a long time and have as much right to be there as anyone.

In the past, huge barriers have been built to keep warring peoples apart. The remains of the wall built

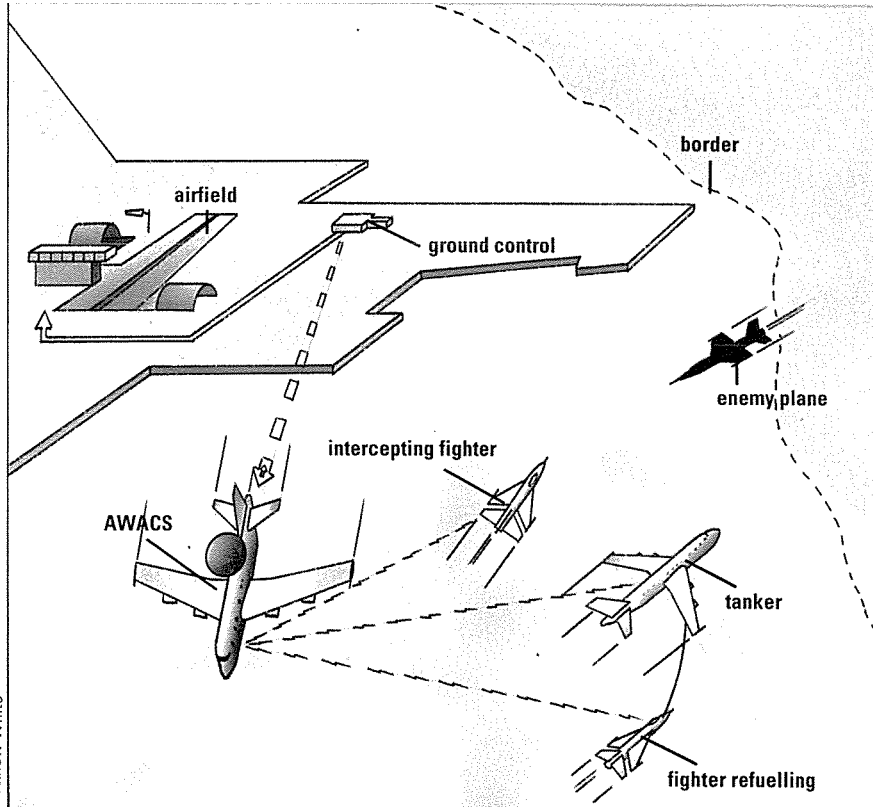
 BORDERS
 REFUGEES
 RADIO JAMMING

Checkpoint Charlie was one of the few places people could cross the Berlin Wall during the Cold War period.

NATIONAL SECURITY

ZEFA





Huge AWACS aircraft patrol nations' frontiers. Loaded with airborne warning and command systems, they detect incoming enemy planes and dispatch friendly fighters to intercept them. Fighters on patrol are kept ready at all times by refuelling them in the air.

from Eastern European countries.

Despite all their efforts, the Soviet Union and East Germany could not prevent large numbers of people sneaking through into Berlin and escaping to the West. So in 1961, they built a wall across the city. Completed very rapidly, this structure became a grim symbol of the division of the world into capitalist and communist nations.

Glasnost

In the late 1980s new atmosphere of openness – or *glasnost* – in Eastern Europe, countries such as Hungary started to dismantle their border defences. And in 1989 The Berlin Wall itself was broken up.

While in one part of the world, barriers have been coming down, in another – North Africa – they have been raised up. In 1975, the former Spanish colony of Western Sahara was invaded by Morocco who claimed that it was part of their country. Local resistance fighters, the Polisario guerrillas, began to wage a war against the occupying Moroccan forces from bases across the border in Mauritania.

Sand wall

In 1980, in an attempt to stop the guerrillas infiltrating across the border the Moroccans began building a huge sand wall extending out into the Sahara and covered with people-sensing equipment (unattended Ground Sensors or UGS) developed by the Americans during the Vietnam war.

Meanwhile, the USA is building its own fences at home now, this time along its border with Mexico. Huge numbers of illegal immigrants trying

by the Roman Emperor Hadrian can be seen in Northumberland in the north of England. Hadrian had the 113 km wall built to keep marauding Pictish tribesmen, who lived in what is now central Scotland, out of the Roman province of Britain.

The Romans built other walls along the River Rhine and River Danube to keep back the 'barbarians'. But none of these compares with the Great Wall of China. Built on the orders of Emperor Shih Huang Ti to keep out the Huns, the

people in Eastern Europe reaching the West. This frontier largely followed the line where the armies of Britain, France and the USA met those of the Soviet Union after Germany had been defeated at the end of World War II.

Germany was divided into two – West Germany and the communist East. The country's capital, Berlin, and the eastern part of the city became the capital of East Germany. West Berlin soon became a magnet for people trying to escape



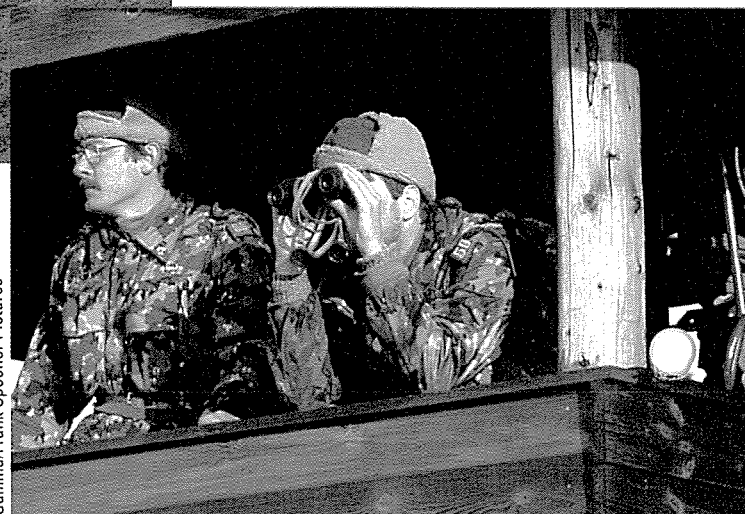
Gamma/Frank Spooner Pictures

Great Wall stretches over 2,000 km around the northern border of China. It is probably the largest building project ever undertaken.

In more recent times in Europe a wall was built in Berlin, part of a massive defensive frontier which stretched across Europe from the Baltic Sea in the north to the Adriatic Sea in the south. This so-called Iron Curtain was made up of vehicle traps, minefields, barbed-wire fences and watch towers designed to stop

The border between communist North Korea and capitalist South Korea. In Europe, the Iron Curtain marked the same ideological border. Communist troops (inset right) look out on the capitalist West.

Gamma/Frank Spooner Pictures





Ric Ferro/Black Star/Colorific!



Cuban refugees flee the communist regime of their island home in the hope of finding a better life in the USA, but many end up in slums.

Special riot squads protect national borders internally, too. Here, French riot police fight Corsicans who want their island to be independent.

In the 1980s Vietnamese boat people left their homeland in millions. They set out across the South China Sea in small boats, braving typhoons and pirate attacks.



Gamma/Frank Spooner Pictures

to escape the poverty, political repression and guerrilla warfare of Central and South America try to cross the Rio Grande from Mexico into the United States each year, in the hope of finding a better life.

In an attempt to stem this flow, the USA has built huge fences along its southern flank. However, the border is still impossible to police thoroughly. In some places, for example, people cross the border each morning and evening on their way to and from work, and it is impossible to check every car in the rush-hour traffic. In addition, the border itself is 2,500 km long. Every night illegal immigrants cut their way through the fences and cross into the USA.

Drug smuggling

America has another problem on its southern border — drug smuggling. Airborne patrols with sophisticated tracking equipment search for the light planes and small boats that bring in the drugs from Latin America.

The United States is not the only country that suffers from the problems of illegal immigration. Hong

Kong, Singapore, Malaysia, Indonesia and Thailand have all been plagued by millions of people fleeing poverty or fighting in the communist regimes of Vietnam, Laos and Cambodia.

Governments not only try to stop people and drugs crossing their borders, they also try to control technology and information. For in-

stance, the US government has banned certain computer equipment being sold to unfriendly powers.

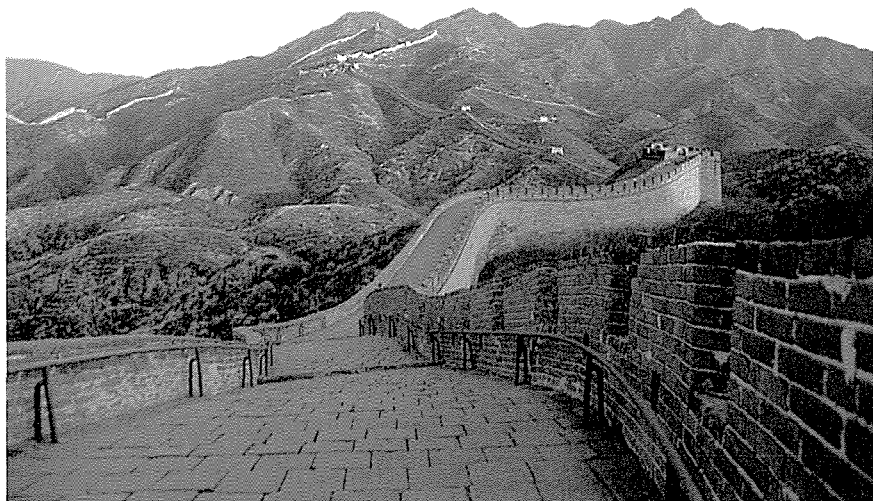
Some countries try to jam radio signals coming from outside by broadcasting jangling sounds on the same frequency as external radio stations. The former Soviet Union jammed Western broadcasts for years, but gave up in the 1980s.

Air and sea

A country's borders also extend up into the air above. Some countries prevent any international airlines flying over their country. Most prevent foreign planes flying over sensitive military establishments. And when planes land, the passengers are checked by customs officials to ensure that they are not intending to settle in the country illegally and to make sure that they are not bringing in drugs, firearms, illegal goods or infectious diseases.

Borders also extend out into the sea. By international agreement, a country controls a 19 km strip of water around its coasts. Some countries have tried extending this limit to protect fish stocks. This has sparked 'wars' between fishermen and navy patrol boats.

The Great Wall of China was the biggest building project ever undertaken. It defended China's northern border from hordes of marauding Huns.



Steven B Williams/Image Bank

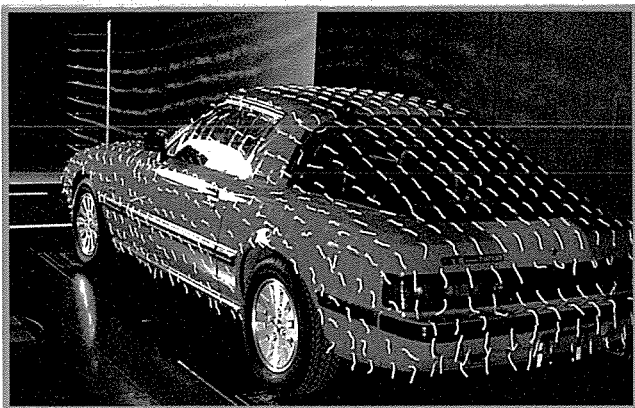




VIEW

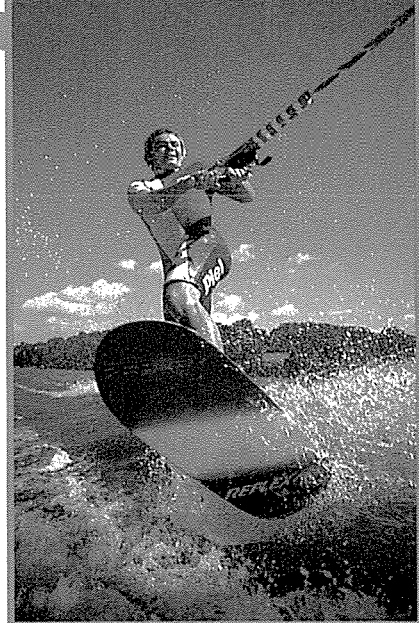
BOUNDARIES

Takeshi Takahara/SPL



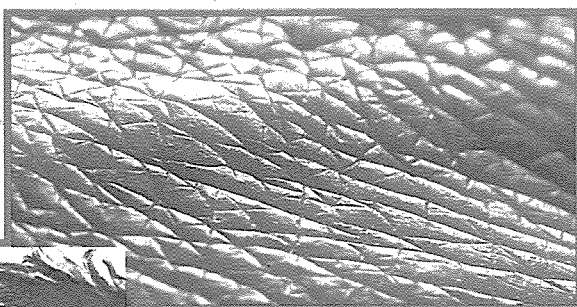
Water skiers speed across the boundary between air and sea.

The boundary layer is the air that hugs a streamlined form. Where the white tapes drop, the boundary layer has separated causing turbulence and drag.



Jean Marc Barey/Vandystadt/Allsport

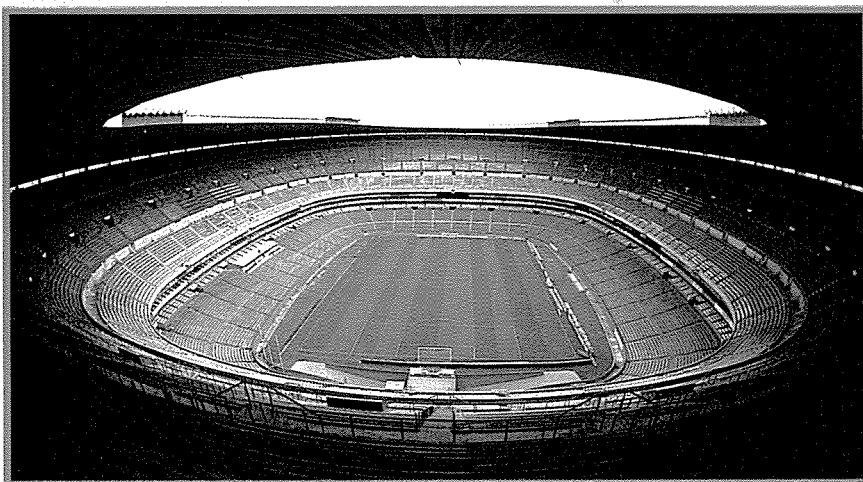
Skin is the boundary between you and the outside world. It keeps the insides in and the outsides out. Under the skin, the white boundary (inset) separates the skin from the flesh.



Martin Dohm/SPL

When you play a game – cricket, football, rugby, basketball – there is a boundary around the pitch that marks the limits of area where play is allowed. There are also inner boundaries.

Astrid & Hans Frieder Michler/SPL



Tony Stone Photo Library, London

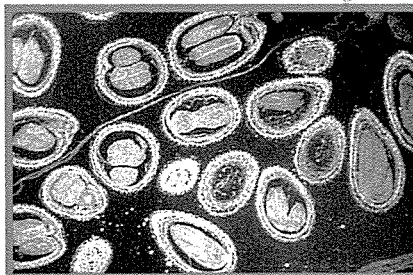
ZEFA



NASA/SPL

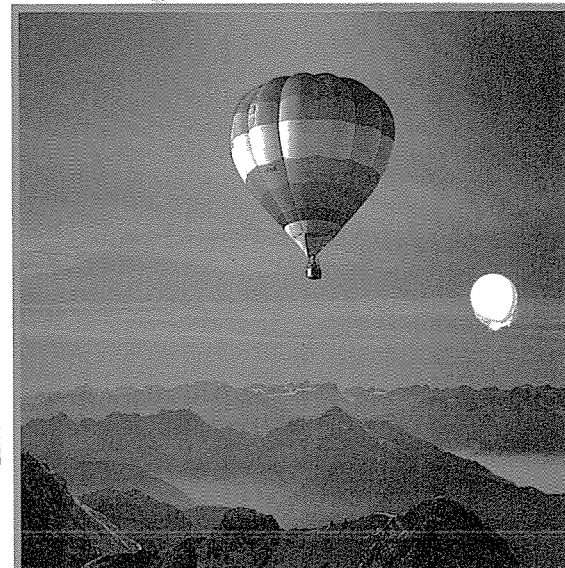
Some patients need an extra boundary between them and the world to keep harmful germs or substances out.

Tiny cells need a boundary or membrane to separate their internal fluid from the external fluid they float in.



Robert Harding Picture Library

In a hot air balloon, the surface of the balloon marks the boundary between the hot air inside and the cold air outside – the difference in temperature makes it fly.



ZEFA

The blue boundary of the Earth's atmosphere is visible from Space – although it looks red when the sun is rising or setting behind it.



THE MANTLE

LIMESTONE CAVE

VOLCANOES

TO THE EARTH'S CORE

A JOURNEY TO THE CENTRE of the Earth from the surface at the Equator to the very core itself would take you through an incredible 6,367 km.

The surface of the Earth, a rough, and wrinkly skin of mountains, hills and valleys, is known as the crust. It is a relatively thin layer of rock, soil and water which can range from being more than 60 km thick in the great continental areas to a mere 4 km depth beneath the sea bed. Granitic rocks rich in silicon and aluminium form the continents. Below the continents and

the oceans is a layer of basalt. This strong, shell-like outer crust, together with the layer immediately below it, 'floats' on top of a softer shell of molten rock — magma.

Going deeper

Below the crust there is a layer of rock known as the mantle, which is about 2,900 kilometres thick and consists mainly of a dense, dark mineral called olivine.

Still deeper is a layer known as the outer core, more than 1,255 km deep, where the iron and nickel within have turned into a gigantic

A limestone cave in South Wales. Most of Britain's limestone was laid down in the Carboniferous period, 345–280 million years ago.

molten mass. The temperature at the inner core, thought to be made of solid iron and nickel, is estimated to be 4,500°C. At the centre, each side of a cube of matter measuring 2.5 by 2.5 cm is under 20,000 tonnes of pressure.

How do we know what is below the Earth's surface? It is very difficult to drill down more than a few kilometres because the farther

PROFILE

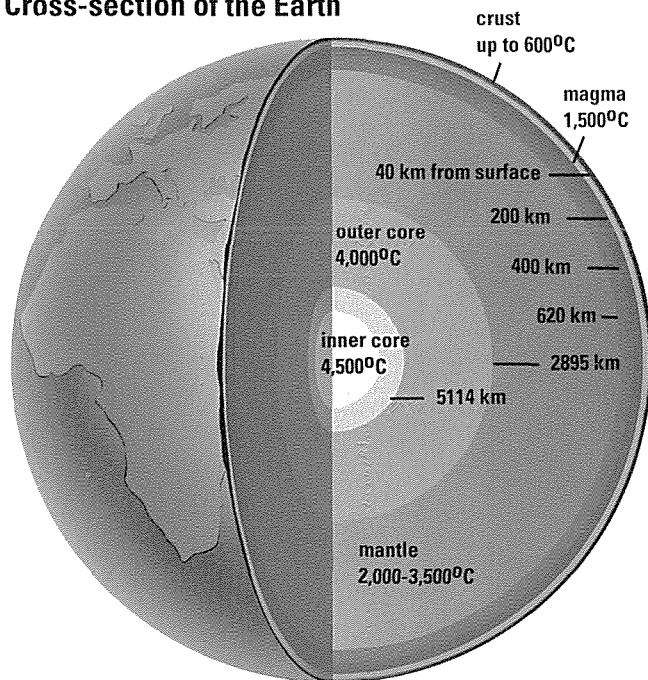
VITAL STATISTICS OF THE EARTH

Age	about 4,600 million years
Weight	about 6,000 million million tonnes
Diameter from Pole to Pole	12,714 km
Diameter at the Equator	12,757 km
Circumference around the Poles	40,020 km
Circumference around the Equator	40,075 km
Surface area of the land	148,328,000 sq km
Largest single land mass (Eurasia)	53,698,000 sq km
Surface area of the oceans	361,740,000 sq km
Total surface area	510,065,600 sq km
Volume of the oceans	1,285,600,000 cubic km
Total volume	1,083,207 million cubic km
Highest point (Mount Everest, Himalayas)	8,884 m above sea level
Lowest point (Marianas Trench, Pacific Ocean)	11,034 m below sea level

Chris Howes/Planet Earth Pictures



Cross-section of the Earth



The Earth is like an onion – a cross-section would reveal a number of layers. Below the crust, the mantle is made of magma – extremely dense, semi-liquid rock. The pressure at the central core is so great that the rock must be solid. Temperatures are estimated.

A 'spelio' – a caver – abseils down a 30-metre waterfall in the Diccan Pot cave system under the Yorkshire Dales of north-east England.

layers of limestone. This is because water containing dissolved carbon dioxide from the atmosphere and soil above slowly wears away the limestone.

If the water table lowers, the

down you go, the higher the temperature and pressure. It has been said that a city on the Moon could be built more easily than a house 25 km below the surface of our own planet.

Volcanoes have provided clues to the structure of the lower crust and the mantle; geologists analyse rocks, lava (molten rock) and ash thrown out through a volcano's crater from deep beneath the Earth's surface.

Shock waves

The technique that reveals most about the structure of the Earth is reflection seismology. In this technique, artificial shock waves created on the Earth's surface are reflected back from rock layers deep within the crust. The way these reflected shock waves behave is picked up by sensitive detectors called geophones. By moving the detectors around and taking a variety of readings, a detailed computer-generated, three-dimensional image of the Earth's crust can be built up. Petroleum geologists have used this method to detect major oil and gas fields.

Another way to find out what is underground is to go down and explore via a cave. The study and exploration of caves – natural underground cavities – is called speleology.

Water action

Sea caves are excavated when waves beat upon weak places in a cliff. Tectonic caves are formed when layers of rock separate or crack. Such caves usually have narrow openings called fissures.

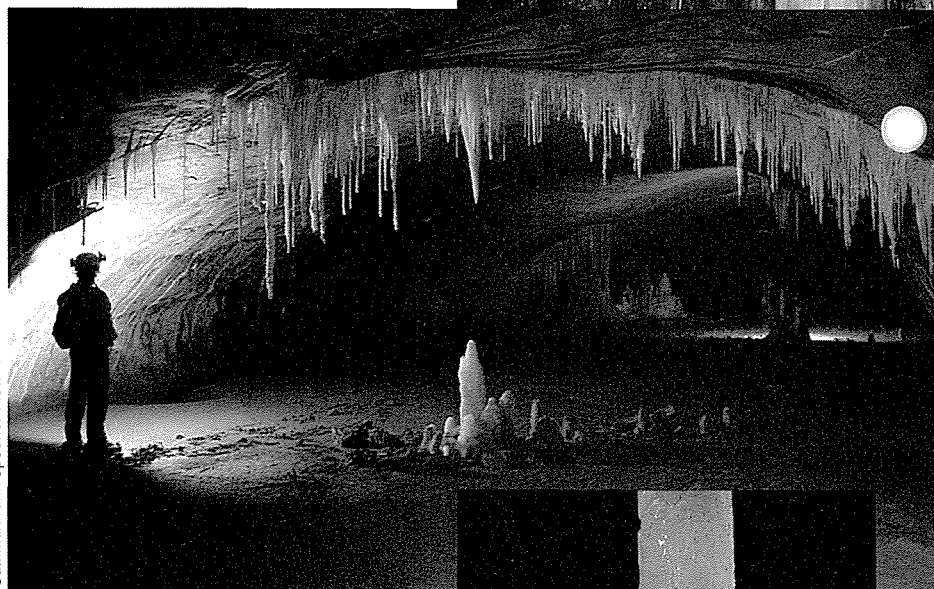
A lava flow, pouring out of a volcano, cools and solidifies first on the top, bottom and sides. Then the liquid in the centre may drain away, leaving a cave. As a lava cave is

very close to the Earth's surface, it is easily eroded. Lava caves are usually found in recent lava flows – recent meaning less than 20 million years old.

Many caves are created by the action of underground water. The

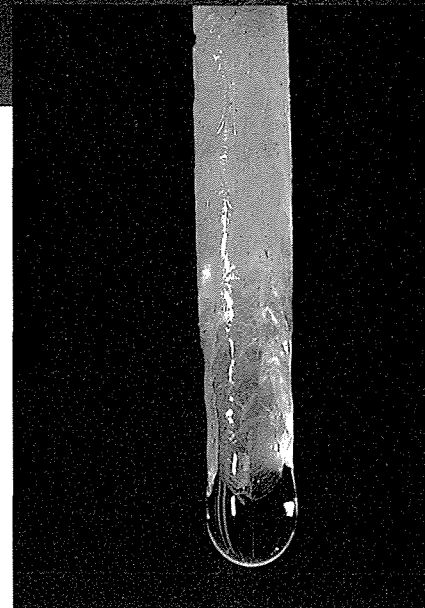


Tony Waltham



Gamma/Frank Spooner Pictures

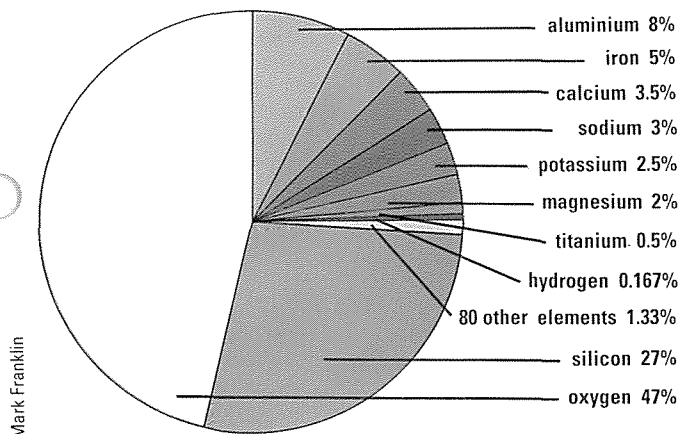
Stalactites in an underground cave resemble a curtain of icicles. A straw stalactite (right) has the diameter of a drop of water. Evaporating water leaves a deposit that slowly forms a stalactite.



Chris Howes/Playarth Pictures



What is the Earth's Crust Made Of?



water in the cave system drains away, allowing air to fill its place. The water does not disappear completely – making its way down from the ground surface to the water table below, it runs through underground caves in streams and waterfalls. Where its passage is blocked, it accumulates in underground lakes.

Stalactites

Water dripping from the roof of a limestone cave is saturated with calcium bicarbonate. As each droplet falls, some of the water evaporates, leaving a tiny amount of calcium carbonate behind. Gradually a calcium carbonate 'icicle' grows down from the roof. This is called a stalactite. Water that drips on to the floor deposits calcium carbonate in the same way. A mound that looks like an inverted icicle develops. This is called a stalagmite. Sometimes a stalagmite grows to meet a stalac-

tite hanging from the roof to form a single column.

A volcano is a fissure or vent (pipe-like hole) from which solid rock, lava, gas and ash erupt on to the Earth's surface. The Earth's crust and upper mantle are divided into plates, which float on the magma below. Unstable zones exist where two plates meet. It is here that most volcanoes occur.

Volcanic islands

Volcanoes are often shaped like cones or domes. A cone is formed from ash and stiff, viscous lava that cools into rock fragments. A dome is made up of fluid lava that has now cooled into a solid mass. A volcano on the sea bed may build up its cone or dome until

The crust of the Earth is made of basic substances called elements. Almost all the rocks in the crust are made from just eight of these elements.

Cave diver Kurt Amsler carries his own oxygen supply as he explores a sump – a passage filled to the roof with water.

TO THE EARTH'S CORE



the top projects above the sea. Many islands are actually the tips of volcanoes: 90 per cent of the two Hawaiian volcanoes, Mauna Loa and Kilauea, are under the sea.

In some volcanoes, such as Mount Fujiyama in Japan and Tenerife's El Teide, escaping gases force out a huge and spectacular cone-

Kurt Amsler/Planet Earth Pictures



Science Photo Library

El Chichon volcano in Yucatan, Mexico, after eruptions in 1982. A sulphur-laden plume of ash was hurled 16.8 km into the atmosphere.

shaped plume of smoke which contains ash, cinders and large lumps of rock. Other volcanoes may look like quiet lakes, such as those in Bolzena and Laziale, Italy, but are in fact volcanic craters filled with water during a 'resting period' between eruptions that may last as long as 20,000 years.

Lava flows

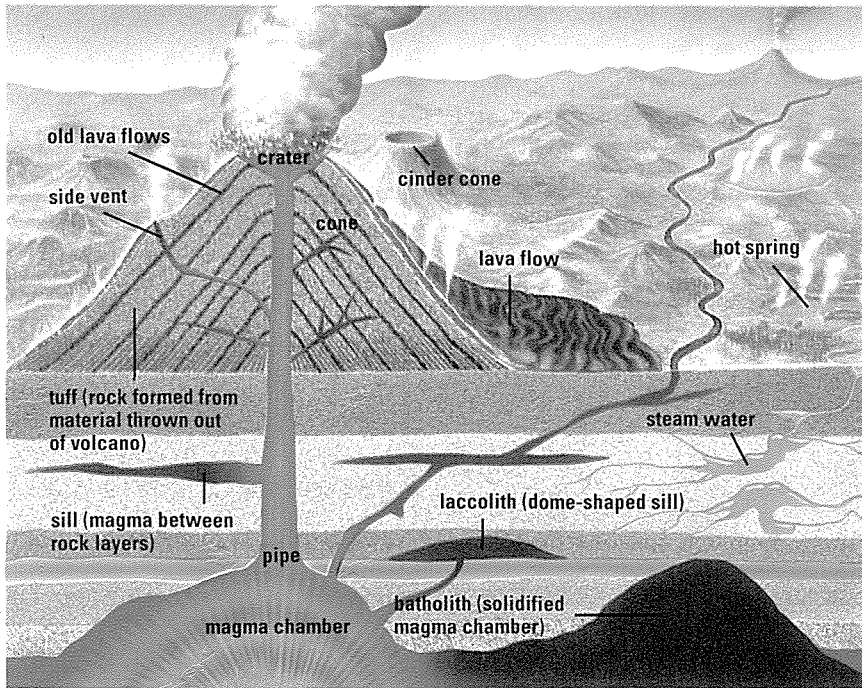
There are also volcanoes simply made up of cracks in the ground that release glowing hot lava flows, which can consume local villages and devastate the countryside.

Kilauea is one of the two active volcanoes on the 'Big Island' of Hawaii. Since 1983, massive amounts of magma have burst through to the surface, emerging as highly fluid lava that flows down the side of the volcano and hardens into rope-like coils.



Philip Chapman/Planet Earth Pictures





John Carty

Volcanoes are like safety valves in the Earth's crust. When the pressure of the magma exceeds that of the rock above, it shoots to the surface.

Lava flows are common on Hawaii and also in Iceland.

Volcanoes are classified into five main types:

- **Hawaiian** volcanoes emit lava from far below the Earth's crust. It pours down their sides, which have broad summits built up from layers of cooled lava and ash. Hawaiian volcanoes are particularly noted for their spectacular fire fountains, which leap high into the air
- A **Stromboli** volcano's lava comes from within the crust. This lava is not as fluid as that from a Hawaiian volcano and is often held under pressure until, in bursts, lava and glowing ash explode out of the

crater into the air.

- **Vulcanian** volcanoes are under even higher pressure and have more powerful eruptions, throwing out huge rocks within dense clouds of ash and cinders that fall back on the volcano, building up a steep cone
- The most explosive of them all is a **Plinian** volcano – so explosive that the cone may collapse in on itself
- A **Pelean** volcano throws out a cloud of ash and hot gas, which then roll down the side of the mountain in a glowing avalanche.

Darkening skies

Thirty four died in 1980, when Mount St Helens, a long-dormant volcano in the north-western corner of the United States, erupted. The explosion blew the top off the volcano, creating a 20,000-metre column of ash so dense it darkened the skies some 250 km away at Walla Walla.

Fumaroles are openings in the ground in volcanic areas, through which steam and gases escape, carrying dissolved elements and compounds such as sulphates, chlorides, sodium and iron. Mineral deposits, for example sulphur crystals, collect around the fumarole. On Mount Erebus in the Antarctic, steam has frozen around the fumaroles, creating spectacular ice chimneys 20 metres high.

Fountains of steam

A hot spring is similar to a fumarole, but contains much more water, which comes from underground water running through cracks in the rocks. A geyser is a spectacular fountain of hot water and steam that shoots into the air. It is named after the 'Great Geyser' of Iceland which was active for more than 350 years, until the 1930s. The water can be well above boiling point.

Wide cracks appeared in the main road of La Reunion, an island in the Indian Ocean, when La Fournaise, the island's volcano, swelled before erupting violently in 1986.

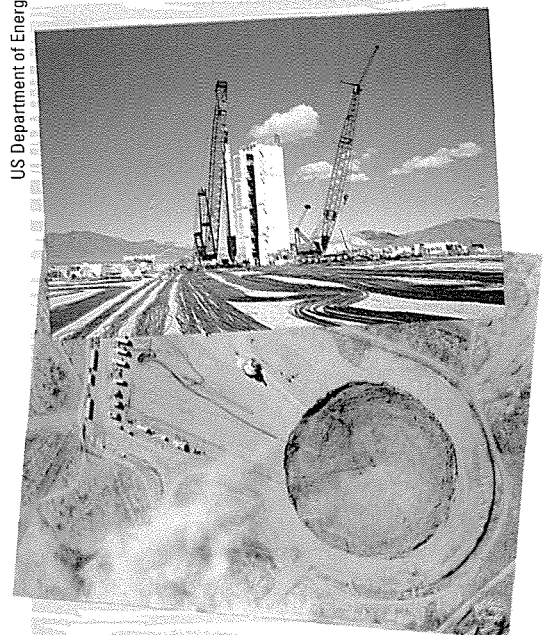


Gamma/Frank Spooner Pictures

NUCLEAR TESTS

It is much safer to test a nuclear bomb by exploding it underground, rather than on the surface. The Nevada Test Site is an 320,000 hectare site in the desert 104 km north-west of Las Vegas. Working from a tower, scientific instruments are mounted into a canister,

US Department of Energy



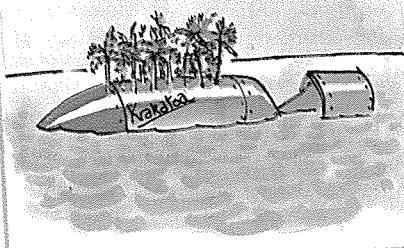
US Department of Defense

which is lowered underground, with the weapons canister. Cables send information from the instruments underground to monitoring equipment in trailers on the surface. In the 1980 Huron King nuclear test, pictured here, a crater 100 metres wide and 30 metres deep was created by a nuclear device detonated 300 metres below ground.

Just amazing!

MEGA-BLAST

THE ERUPTION OF KRAKATOA IS STILL THE GREATEST EXPLOSION EVER RECORDED. THIS VOLCANIC ISLAND IN INDONESIA WENT UP IN 1883, WITH 26 TIMES THE POWER OF THE LARGEST H-BOMB EVER TESTED.



Paul Raymond



EARTHQUAKE!



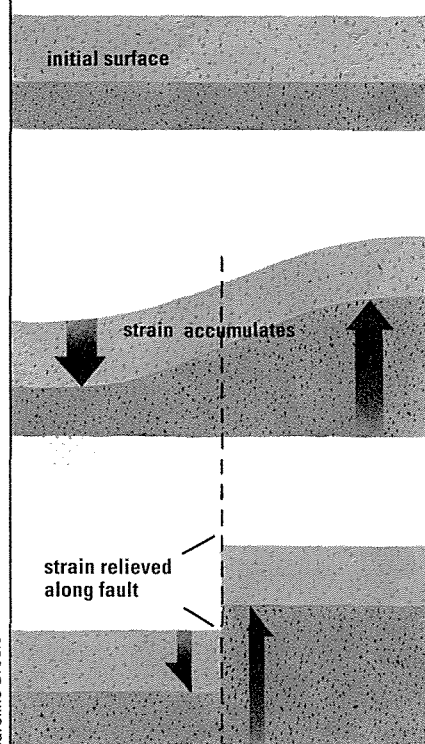
Gamma/Frank Spooner Pictures

 SHOCK WAVES

 SEISMOGRAMS

 RICHTER SCALE

A Fault Line



Caroline Brodie

THE GROUND BENEATH YOUR feet begins to vibrate violently. Walls shake, the ceiling cracks and windows shatter. Loose objects are overturned. A loud rumbling tells you that you are caught up in an earthquake. If you are lucky, the tremor will pass without major damage.

But earthquakes can sometimes be devastating in their effects. Whole towns, and even regions, have been flattened. Cracks in the ground swallow up buildings. Fires and floods may follow, and tidal waves may cause large-scale flooding. The worst earthquakes have claimed hundreds of thousands of lives and caused untold misery.

Long or short

Most earthquakes last for less than a minute, but in 1966, an earthquake in Tashkent, USSR, lasted for 38 days! Fortunately, earthquakes on this scale are very rare. Of the million or so earthquakes every year, only about a thousand are ever felt on the surface and only a few cause any damage. Many are under the sea, or so tiny that they can barely be detected.

Earthquakes are the result of severe shock waves passing through solid rock in the Earth's crust. These occur when layers of rock are gradually stretched or compressed so that they deform into basins or

The Earth's crust will bend only so far, under the pressure caused by plates colliding. Then it will snap along a fault line, sending out shock waves.



Gamma/Frank Spooner Pictures

The devastation caused by an earthquake can range from cracks in the ground to the full-scale destruction of buildings, as in Armenia (top).

folds. If the strain is sudden or too great, the rock may fracture and shift abruptly. At one end of the scale such rock movement may have a relatively small effect, such as when rocks collapse over a cavity, or gravitational forces on a cliff edge cause an avalanche.

The more violent earthquakes, which present a threat to life and property, are caused by movements of the Earth's tectonic plates. These plates, which lie underneath the major continents, are constantly moving very slowly. In places where



two plates push or slide against each other, stresses build up in the rock. The rock will change shape to a certain degree, but when it reaches its limit, it breaks at the weakest point, creating a 'fault' line and sending shock waves to the surface. The shock – or seismic – waves travel outwards from the centre of the earthquake, known as the focus. The focus is often deep in the Earth's crust, and the point on the surface immediately above it is called the epicentre. When the earthquake occurs very deep in the Earth there may be no surface displacement.

Secondary effects

However, as the shock waves hit the surface, huge ripples may spread across the land, which may bulge and crack and close up again. The land waves which occur close to the epicentre can trigger off rockfalls, landslides and avalanches which can cause as much damage as the original earthquake. The secondary effects of an earthquake may be collapsing buildings, ruptured dams, gas or water pipes and the consequent fires and floods.

Earthquakes can also generate huge sea waves known as tsunamis. Produced by displacement in the ocean floor, they can cause large-scale devastation. Although they may be only half a metre high out at sea, they build up to great heights



Universal/Kobal Collection

quake reduced it to rubble.

However, there are more scientific clues to an impending earthquake. Just before rocks break apart, their crystal structure may open and close, releasing radon gas into groundwater, which is carried into wells. Monitoring wells may thus give notice that rocks are about to give way.

There are also electrically charged

Flooding can be as destructive as quakes. In this scene from the film 'Earthquake', a dam has burst, and sent millions of tons of water crashing down the hillside, wiping out the houses on the hill below.

BURIED ALIVE



David Leah/Science Photo Library

Dogs are invaluable for tracing victims buried alive under the rubble caused by earthquakes. After the Armenian disaster of 1988, survivors were still being found up to a week after the quake. Soviet authorities stopped clearing the flattened area until they were certain that all survivors were safe.

Gamma/Frank Spooner Pictures



Rex Features

as they reach the coast, where they do most damage. In 1958, a tsunami some 30 metres high hit the Alaskan shore at more than 200 km/h and destroyed large areas.

With earthquakes causing so much damage and suffering, it is important to try to predict when and where they will take place.

Animal behaviour is one way of predicting an earthquake. Just before the onset of an earthquake, dogs sometimes howl, rats have been seen to leave their holes and birds may become restless. In 1976, the people of a Chinese city noticed this strange behaviour and evacuated the city hours before an earth-

quakes which are sometimes released and these produce the faintly-glowing 'earthquake lights' that are occasionally reported. Recently, scientists have also shown that surges of hydrogen, up to ten times higher than normal, can be detected above fault lines prior to an earthquake. None of these effects is common to all earthquakes and so several techniques have been developed to provide a more accurate prediction.

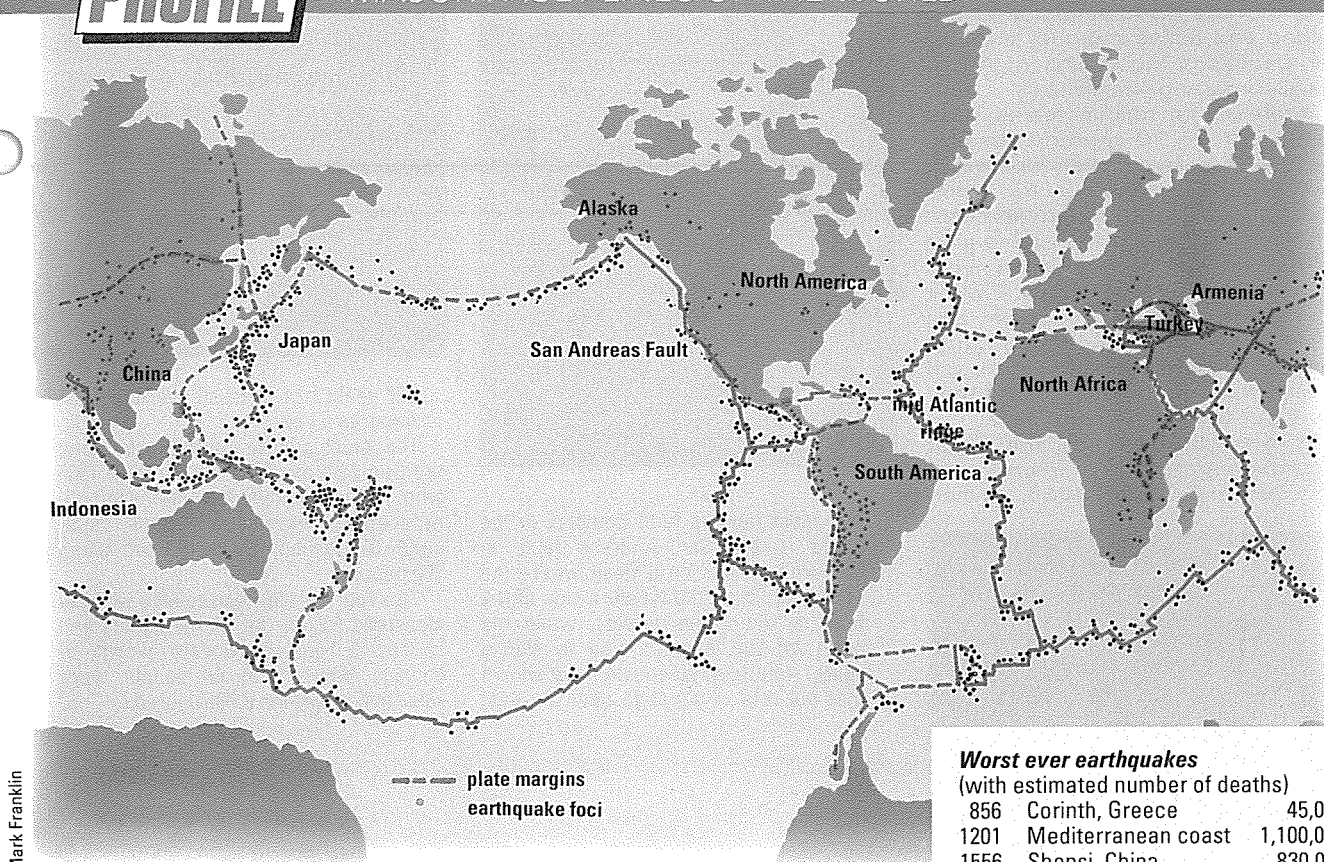
Strain gauges in fault lines (giant cracks that may run for kilometres below or across the Earth's surface), can detect the build up of stress levels. Tiltmeters, sophisti-

When Mexico City was struck by an earthquake measuring 8.1 on the Richter scale in 1985, many people were trapped in the rubble of collapsed buildings. The Special French Disaster Squad was flown in to help dig out survivors, using cranes and heavy machinery, and on September 23, they rescued Leonardo Ventura Lopez. He had been buried alive for five days under the rubble of the Juarez Hospital, which was destroyed in the quake. When he was brought to the surface, he shouted out; "Vive la France!" in honour of his rescuers.



PROFILE

MAJOR FAULT LINES OF THE WORLD



Worst ever earthquakes

(with estimated number of deaths)

856	Corinth, Greece	45,000
1201	Mediterranean coast	1,100,000
1556	Shensi, China	830,000
1703	Edo (now Tokyo)	200,000
1755	Lisbon, Portugal	650,000
1923	Kwanto, Japan	140,000
1935	Kansu, China	100,000
1950	Assam, India	60,000
1971	Yungay, Peru	50,000
1976	Tangshan, China	650,000
1985	Mexico City	10,000
1988	Spitak, Armenia	50,000
1993	Killari, India	10,000

cated versions of the carpenter's spirit level, have a bubble whose movement detects any movement of the Earth's surface. Creepmeters — wires stretched across a fault — show up any sideways movement.

Seismology

However, the most scientific type of earthquake prediction is carried out by seismologists using a seismograph. This highly sensitive instrument can detect small shocks from below the Earth's surface. The small vibrations detected are converted into an electrical current which is amplified and traced on a highly sensitive chart recorder. In this way, the sudden release of stress in rocks which precedes an earthquake can be detected. Where seismographs are left in remote areas and daily readings are not possible, the data can be transmitted to a central station.

A recent technique for monitoring Earth movement involves using satellites to send signals to different fixed Earth stations. The signal net-

work makes it possible for the satellite to pick up information revealing whether the stations have moved position relative to each other.

Seismographs measure the intensity of an earthquake in terms of the energy released and the subsequent vibration caused, and the Gutenberg-Richter scale is used to define this energy. This scale — usually just called the Richter scale — is mathematically linked to the readings on the seismograph in a formula devised by Dr Beno Gutenberg and Dr Robert Richter in 1935. An earthquake measuring 2 on the Richter scale represents the smallest shocks causing slight damage; 6 relates to substantial damage, and 8.9 is the highest reading ever

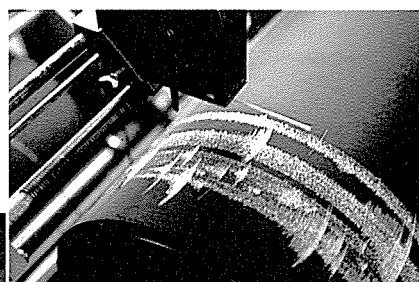
obtained. Few earthquakes exceed 8, but, on average, there is one of these somewhere in the world each year.

Another method of measuring earthquakes is the Mercalli scale which describes what people see or feel during an earthquake. There are several types of such scales which range in observation from small vibrations which cause objects to fall off shelves, to major shocks.

Armenian tragedy

On December 7, 1988, an earthquake near the Turkish border in Northern Armenia measured 6.9 on the Richter scale. It wiped the town of Spitak from the face of the Earth. In Leninakan, (now Kumayr) more than three quarters of the apartment blocks collapsed completely, burying many people with them. The earthquake happened so fast that pigeons sitting on ledges were killed outright, and people died at tables without having a chance to get up.

Other towns near the earthquake suffered similar devastation. More than 50,000 people died as a result



Seismograms — appearing as waves on a chart (above) — predict earthquakes by sensing vibrations in the Earth's crust.



Gamma/Frank Spence Pictures

USGS/HVO



of the earthquake, which occurred in one of the world's most intensely folded and active regions, the Lesser Caucasus Mountains of Armenia, Georgia and Azerbaijan.

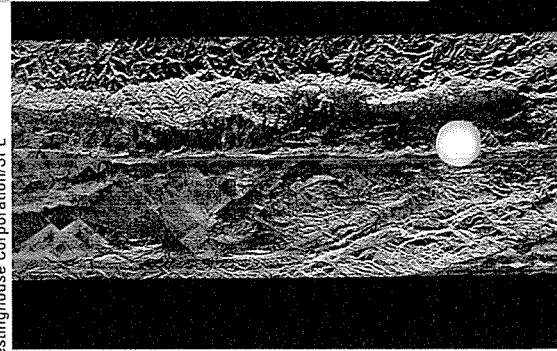
International rescue teams were flown in from 70 countries to help with a massive relief operation, which was not helped by the bitterly cold weather. Five thousand people were dug out of the rubble alive in the first two days, and survivors were still being pulled out a week later. One woman told how she kept her four-year-old daughter alive by slicing her fingers so the girl could drink her blood while they were buried alive for eight days.

In terms of death toll, the worst recorded earthquake in history was on January 23rd 1556, when

David Parker/Science Photo Library



THE SAN ANDREAS FAULT

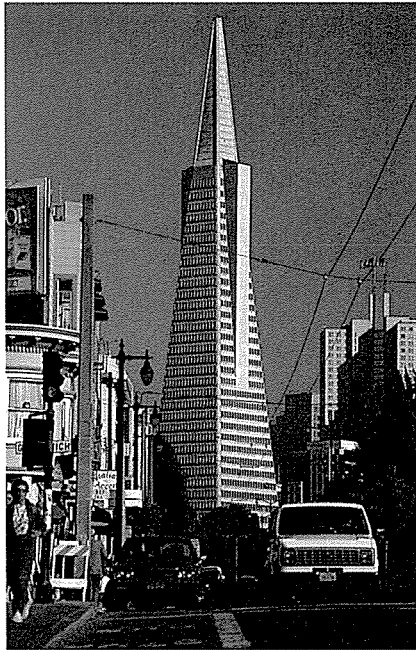


Westinghouse Corporation/SPL

13,000 years has been an average of 36 millimetres a year.

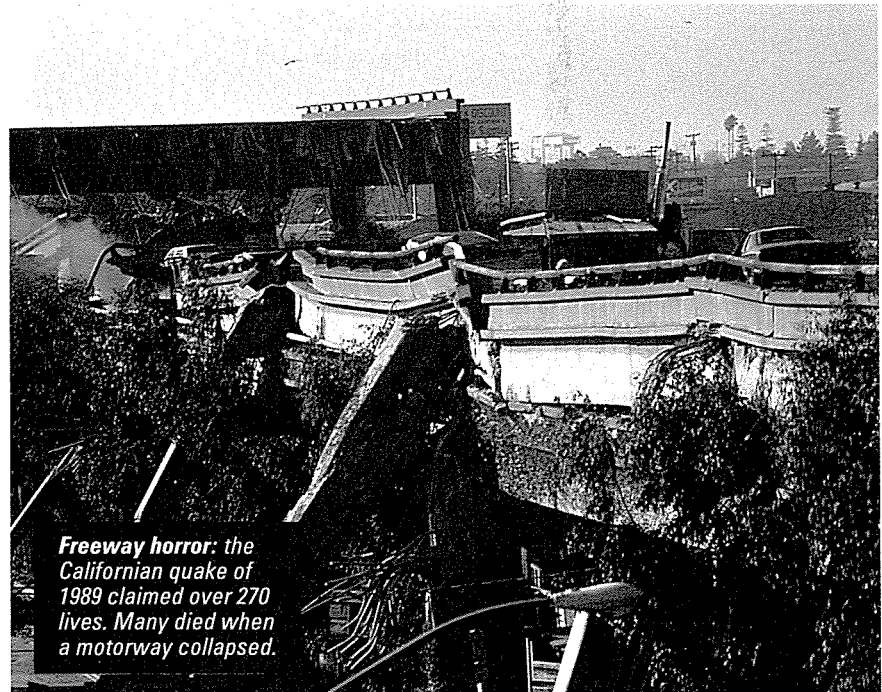
The most severe earthquake along the San Andreas fault occurred in 1906 when a quake lasting less than a minute reduced San Francisco to ruins, causing \$1,000 million of damage and killing 700 people.

The Los Angeles earthquake of 1994 measured 6.8 on the Richter Scale and caused billions of dollars worth of damage. More than 50 people were killed and more than 8,000 injured.



Tony Waltham

'Quake-proof' buildings with flexible internal supports are built in high-risk areas such as San Francisco.



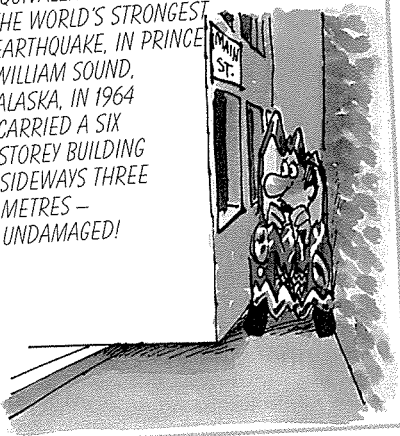
Freeway horror: the Californian quake of 1989 claimed over 270 lives. Many died when a motorway collapsed.

Gamma/Frank Spooner Pictures

Just amazing!

A CRUSH ON YOU

EQUIVALENT TO 12,000 ATOMIC BOMBS, THE WORLD'S STRONGEST EARTHQUAKE, IN PRINCE WILLIAM SOUND, ALASKA, IN 1964 CARRIED A SIX STOREY BUILDING SIDeways THREE METRES — UNdamaged!



Paul Raymond

around 830,000 people died in the Chinese province of Shensi. These figures are certainly more reliable than the estimated death toll of over one million in July 1201, when a massive earthquake devastated cities on the eastern Mediterranean coast and the Near East.

More recently, in 1976, China suffered a similarly devastating earthquake in the heavily populated industrial city of Tangshan where more than 650,000 people died. The Chinese capital of Beijing (Peking) was more than 100 km away but still sustained damage to property.

When it comes to measuring the strongest-ever earthquakes, the Richter scale is limited in its use.

Since 1977, the Kanamori scale has been adopted to measure the energy released during the strongest earthquakes. The most massive quake recorded by any electrical instrument was at Lebu, Chile in May 1960, which measured 9.5 on the Kanamori scale. But this rates only 8.3 on the Richter scale.

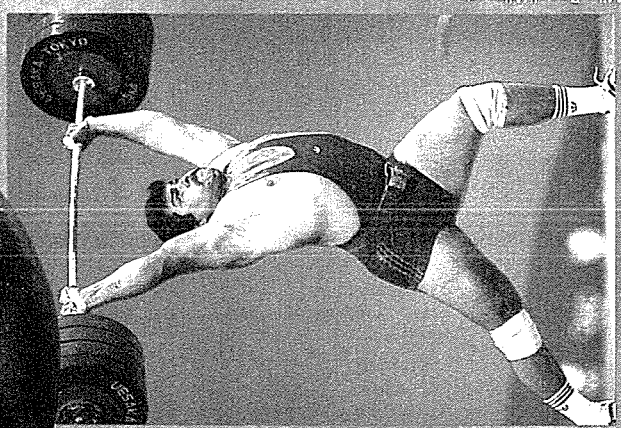
Seismologists have predicted that disastrous earthquakes will be more frequent in the future, because over one-third of the world's largest and fastest growing cities are located in high risk areas. It has been estimated that by 2035, more than 600 million people will be living in major cities within 200 km of tectonic plate boundaries.



SUPREMACY

Bob Gerner/Muscle & Fitness

Mike Powell/Allsport



MUSCLE TYPES

RESPIRATION

ANABOLIC STEROIDS

WHAT MAKES A GREAT athlete? The answer lies in a combination of different factors — genetics, attitude and training. Conventional wisdom has it that great athletes are born and not made.

Without doubt, the genetic make-up of the top sportsmen and women is a crucial factor in their success. For example, people born with a predominance of type 1 muscle, which is pale in colour, make ideal sprinters and jumpers. Those born with type 2 muscle will be good at long distance running. Only rarely do people born with one type of muscle excel in the disciplines which need the other muscle type. Sometimes fibre testing is used to select people for training for

particular running events. Some people are better equipped to deliver oxygen to their muscles — hence their performance improves.

Better breathing

The top athletes have an above average cardio-respiratory system, which means they are capable of a high rate of oxygen transport and carbon dioxide elimination. Top athletes also appear to be genetically programmed to lay down less fat — adipose tissue —

beneath the skin than the average person of the same age and sex. Having less fat means there is less weight to drag around and also makes temperature regulation more effective, so the athlete does not get too hot. Long distance swimmers, however, benefit from large amounts of fat under the skin as it helps keep them warm in cold water.

Body shape also helps determine how suitable someone is for certain sports. A tall athlete may be equally good at high-jumping or basketball.

The rippling muscles of the body builder are purely for posing. He would never be able to match the weight-lifter (above), as the narrow waist favoured by body builders would not be able to handle the strain of lifting up to 470 kg.



whereas an oarsman with a powerful frame may also be a good rugby player. While sprinters tend to be broad-shouldered with muscular legs, the endurance athlete is lean, narrow-shouldered, and not too muscular in the legs. Middle-distance runners such as Sebastian Coe have slight figures compared to the powerful bodies of sprinters like Linford Christie.

Though differences within a field may be small, they can determine who will become a world champion and who will be second-best.

Will to win

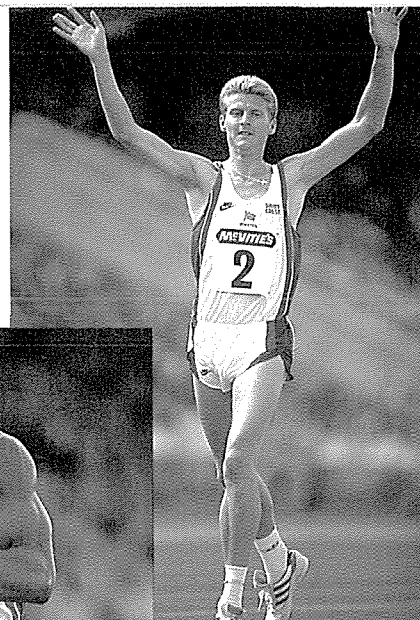
State of mind is an essential part of performance. In a sport like weightlifting, the athlete must psyche himself up for an explosion of power which is usually accompanied by a loud shout. Concentration is important in any explosive sport so that the athlete can channel all his energy into the activity. You only have to look at the faces of sprinters, high jumpers, or shot

putters before they perform to see the intense concentration on their faces.

However, there are no golden rules which apply to all sports. For example, former Wimbledon tennis champions Bjorn Borg and John McEnroe had completely different temperaments. Borg showed no obvious tension and appeared to be totally in control of his emotions (he also had an abnormally low pulse rate). But McEnroe only seemed to play his best when he was wound up to the point of hysteria.

Self-belief and confidence are particularly important in sports where competitors are well matched — the 'will to win' can often be the deciding factor. Athletes try to boost their self-confidence by visualizing themselves performing at the peak of their ability. They hope to translate this mental rehearsal into success during the real competition. Sports psychologists can help athletes to think positively. Top English football club Tottenham Hotspur employed sports psychologist, John Syer, for a five-year spell in the 1980s which included three major cup wins.

Determination is etched all over the face of teenage tennis star Michael Chang. While some players need to get 'hyped up' to play their best, others rely on keeping a cool head.



Gray Mortimore/Allsport

Middle distance runners such as Steve Cram have a predominance of Type II muscle, helping endurance, while power athletes like Linford Christie (left) are much more likely to have Type I muscle in abundance.

Gray Mortimore/Allsport

It is said that practice makes perfect. In some sports such as swimming, gymnastics and tennis, the top stars can reach the pinnacle in their teens, having trained intensively from an early age. But most athletes peak in their twenties, when they can combine athletic ability with the experience of competition.

Training is vital to help athletes realise their genetically-endowed potential and reach the top. It helps them increase their strength, endurance and flexibility. In team sports,

A fitness chart showing which types of exercise are best for different aspects of fitness. The darker the blue, the better.

	badminton	baseball	basketball	canoeing	cricket	cycling	dancing	fencing	US football	football	gymnastics	hockey	horse-riding	ice-skating	jogging	judo	mountaineering	roller-skating	rugby	running	skiing	skipping	squash	swimming	table-tennis	tennis	volleyball	walking	weight-training
endurance fitness (stamina)																													
muscle endurance																													
muscle strength																													
skill factor																													
flexibility																													
relaxation																													
availability																													

low

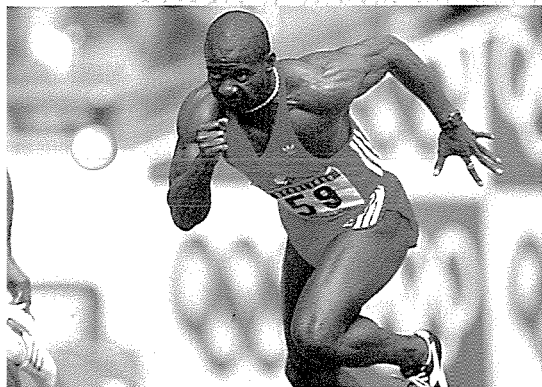
medium

high

Mark Franklin



DRUGS IN SPORT



Tony Duffy/Allsport

Many athletes and body-builders use anabolic steroids to build up their muscles. These drugs are based on the male sex hormone testosterone and they enable athletes to build up more muscle bulk than drug-free athletes. But steroids are banned by most athletics organisations, partly because they are unfair on 'clean' athletes, and partly because of the harmful side effects. These include increased aggression, psychosis and brittle bones. Steroids increase the levels of testosterone, and some women have been known to grow excessive facial hair and stop menstruating. In severe cases, steroids can be fatal. They can be detected in urine samples, and it was this test which caught the Canadian sprinter Ben Johnson at the 1988 Olympics. He was subsequently stripped of his 100 metres gold medal and the 1987 world championship.

Another dangerous practice is 'blood-doping'. The athlete drains off up to a litre of blood, freezes it for a month, and then reinjects it close to an event. This increases the oxygen-carrying red blood cells. It is not illegal, but it is unfair.

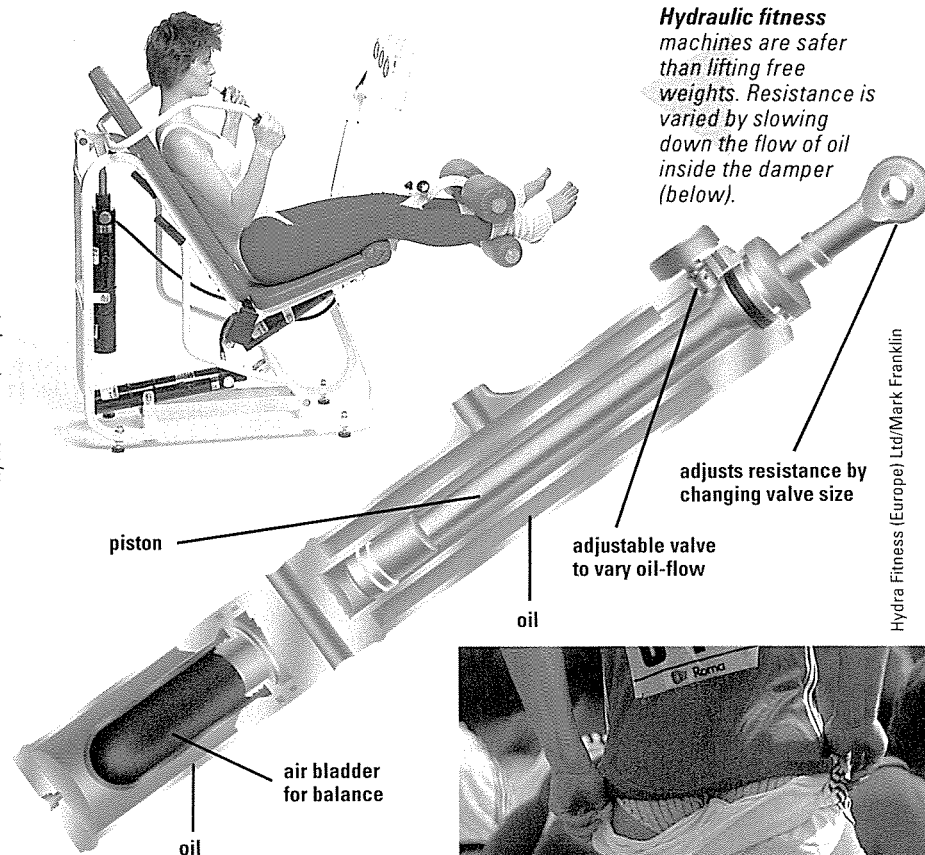
training increases the players' awareness of each other.

In activities that demand a high oxygen supply to the muscles, training raises the capacity of the body to take in oxygen and transport it efficiently. When athletes are in full stride, the rate of blood flowing to the muscles is up to 30 times higher than normal thanks to a stronger heartbeat and faster

load up with carbohydrate in the days before a race. This builds up a reserve energy store of glycogen in the muscles and liver. Although fat can supply twice as much energy, it releases it more slowly. The top marathon runners are thought to obtain around 80 per cent of their energy from glycogen and only about 20 per cent from fat.

The recently opened Olympic

Hydra Fitness (Europe) Ltd



Hydraulic fitness machines are safer than lifting free weights. Resistance is varied by slowing down the flow of oil inside the damper (below).

Hydra Fitness (Europe) Ltd/Mark Franklin

Injuries are a problem for all grades of athlete. Overtraining can be one cause, as well as the pressure to carry on when hurt, which increases the damage.

heart rate than the average man. Regular exercise also increases the endurance capacity of the muscles.

In sports where skill is required, such as football or tennis, the level of ability can deteriorate as the athlete tires.

Training science

Power training, such as weight-lifting, increases the size of muscle fibres and hence the size of the muscles. On the other hand, if muscles are not used they tend to waste away. Scientists are now developing techniques to make athletes fitter, faster, stronger and better than ever before. In recent years, scientists and doctors have played an important part in helping sportsmen and sportswomen reach new heights of performance.

Diet is particularly important for the endurance athlete, who may



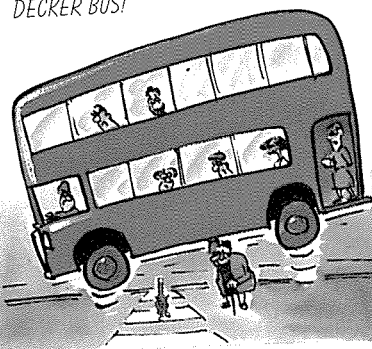
Action-Plus

Medical Centre in Northwick Park, London, is an example of what state-of-the-art sports science is now providing. For example, in the aerobic laboratory, athletes are tested for their ability to exercise while fuelling the muscles with oxygen — called aerobic respiration. The athlete is asked to work progressively harder by perhaps increas-

Just amazing!

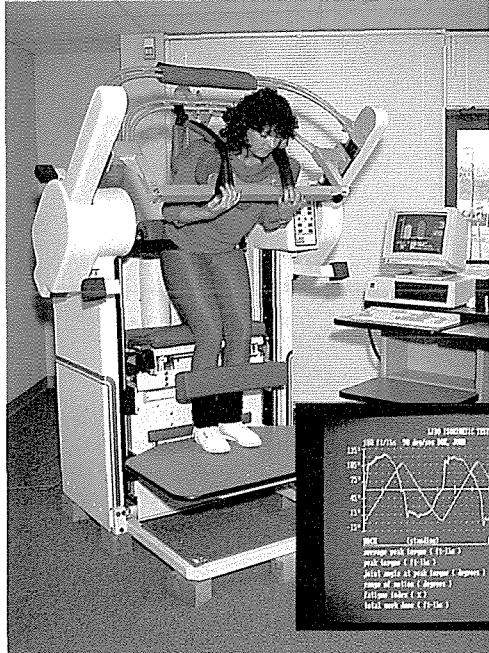
ALL FOR ONE

IF ALL THE MUSCLES IN A HUMAN BODY PULLED TOGETHER, THEY WOULD HAVE ENOUGH STRENGTH TO LIFT A DOUBLE DECKER BUS!

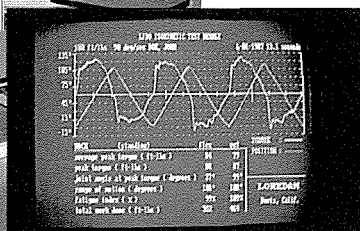


Paul Raymonde

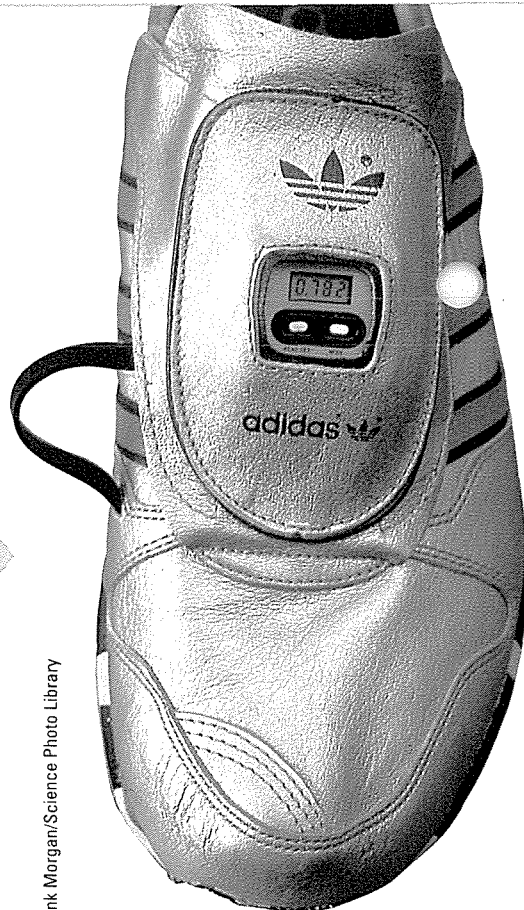




An isokinetic dynamometer can be used to measure the strength and consistency of different groups of muscles. It displays the information on a computer screen (inset), and this will tell the athlete which muscles need working on most in training. Most of these machines can also be used to build up strength.



The computerized running shoe can tell you how much distance you have covered, how long it has taken, and your speed. The data is presented on a liquid crystal display.



Hank Morgan/Science Photo Library

ing the angle of incline of a treadmill – a sort of conveyor belt whose speed is adjustable – and measuring the increasing amount of oxygen taken in at each breath.

Oxygen debt

When the oxygen uptake reaches a maximum, the body switches to anaerobic respiration – providing energy in the absence of oxygen. But this leads to a build up of lactic acid, a waste product that circulates in the blood and muscles and leads to fatigue and exhaustion. The pain in the legs after a long run is the result of lactic acid build-up, or 'oxygen debt' as it is known. Scientists take blood samples during testing to identify the point, known as the anaerobic threshold, where the lactic acid in the blood rises.

This information is very helpful to athletes, because if they reach this threshold too quickly, they have to stop. The best way to train is to work just below the threshold.

An important test for people who play 'multiple sprint' sports such as football, involves working them flat out for 30 seconds and then measuring their performance. If the test is repeated 30 seconds later, it gives a measurement of the speed of recovery from fatigue, and their training can be adjusted to improve the recovery rate.

Overtraining

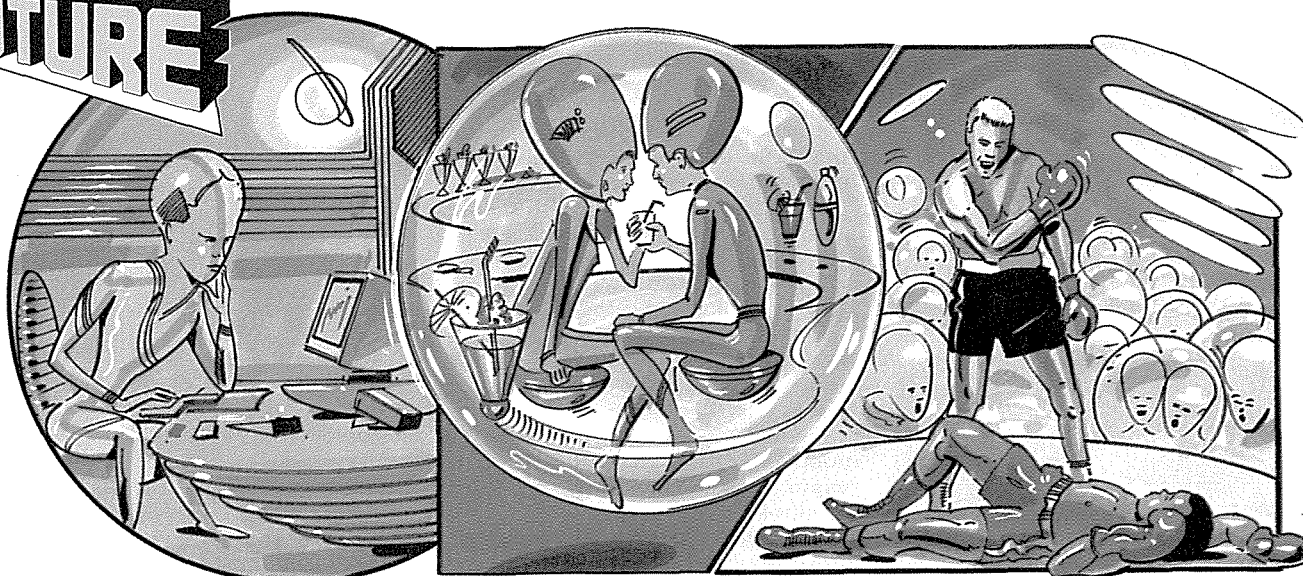
Training can sometimes be harmful. Gymnasts who start performing before they are ten can suffer crippling back pain by the age of 25, as a result of too much strain on their muscles and joints. Promising

young tennis players have been racked with injuries after competing too hard from an early age.

Young people are particularly vulnerable to injury during the peak growth years, in their early teens. This is because as bones grow longer, they stretch the muscles and tendons anchored at the elbows, knees and ankles, which makes them more liable to injury. Young people must be instructed carefully to prevent 'burn out' later.

INTO THE FUTURE

MIND OVER MATTER



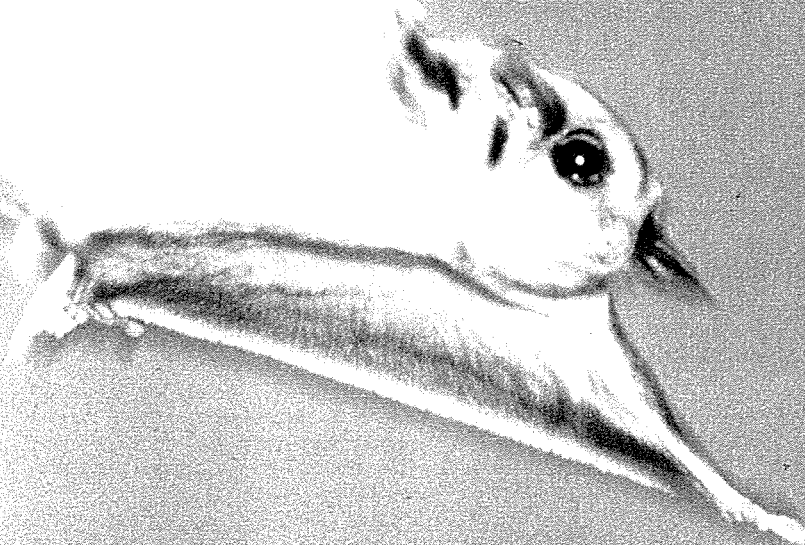
▲ As technology takes more and more of the physical tasks away from Man he will evolve around his major organ – the brain.

▲ Eventually Man will learn to use his brain to its full extent, communicating by telepathy and moving objects by psychokinesis.

▲ There may still, however, be a need for some 'primitive' human models for entertainment work such as films and sports.

ADAPT OR DIE

A possum takes to the air on outstretched folds of skin to glide from tree to tree. In a million or so years from now, this feature might evolve into flight with wings similar to those of today's birds.



Mike Price/Survival Anglia

Bruce Coleman Ltd

-  NATURAL SELECTION
-  CAMOUFLAGE
-  MIMICRY

EVERY LIVING THING – including humans – has evolved through natural selection. By this process, plants and animals survive and produce offspring only if they have appropriate adaptations to their environment.

A good example of natural selection at work is the long neck of the giraffe. It is thought that most

A hummingbird in captivity, feeding. It is well adapted to hovering, and even flying backwards, as it feeds on nectar in flowers – a source of food only insects can usually tap.

giraffes once had a much shorter neck, but when the foliage they ate from trees became sparse, only those giraffes that could reach the remaining, higher leaves survived. In turn, they produced off-spring with similarly long necks and the shorter-necked giraffes died out.

Adaptation

Humans have adaptations to different climatic regions. An example of this adaptation is the colour of skin in different races. Humans evolved in a tropical sun, so they have cells that produce melanin – a dark pigment in skin which helps block the Sun's harmful ultraviolet rays.

As humans migrated to colder, less-sunny areas, their skin did not require the same level of protection from ultraviolet rays, so they evolved a lighter skin.

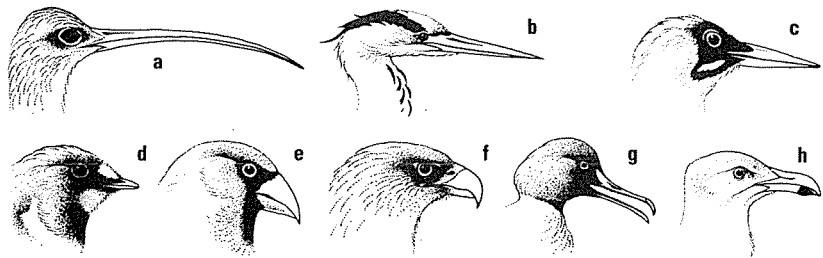
Other animals, and also plants,



have evolved over millions of years to survive their particular habitat. In the polar regions, animals like the Arctic fox and Arctic hare evolved the ability to change colour with the seasons to escape predators. In summer, their coats are brown to match the ground, and in winter snow they change to white.

Jungle apes have exceptionally well developed hands, feet, and tail, enabling them to swing from tree to tree. Some species of South American monkey have 'prehensile' tails — tails they can use as an extra limb to hold on to branches.

MAIN TYPES OF BILL



The length and shape of a bird's bill are strong indications of its feeding habits and type of habitat. The long, curved bill of the curlew (a) is ideal for probing soft mud. The dagger-like bill of the heron (b) is useful for grabbing fish near the surface. The woodpecker's bill (c) is

strong and chisel-like. The swallow (d) has a huge gape to capture insects in flight. The powerful bill of the hawfinch (e) cracks nuts. The eagle (f) is adapted for tearing flesh. The goosander (g) is clearly a fisher. Gulls have an all-purpose bill (h).

Some tree-dwelling animals, including mammals and reptiles appear to be in the process of evolving the ability to fly. The Paradise tree snake can flatten its body into the shape of a curved ribbon to glide from tree to tree.

The flying lemur of southeastern Asia achieves the same effect with flaps of skin that stretch out like wings at its sides when the lemur spreads its legs. And Wallace's flying frog stretches out its webbed feet to glide from tree to tree.

The desert heat

Many animals have adaptations to living in dry, hot, sandy deserts. Camels, for example, have broad toes which prevent their large bulk sinking into the sand. Gerbils and kangaroos move across the desert in giant leaps, and gerbils have tufts of hair on their feet to insulate them from the hot sand.

Plants that live in dry regions usually have a huge network of roots to reach water deep beneath the ground, as well as systems to store water and reduce its loss. The

cactus is particularly good at retaining water. Its swollen stems and fleshy leaves are really store houses for water.

Tricksters

Many species have evolved mimicry as a form of defence against predators. Some harmless animals have evolved certain colours or shapes to mimic dangerous or poisonous species. Predators know that such a species should be avoided and so are fooled into leaving the harmless species alone.

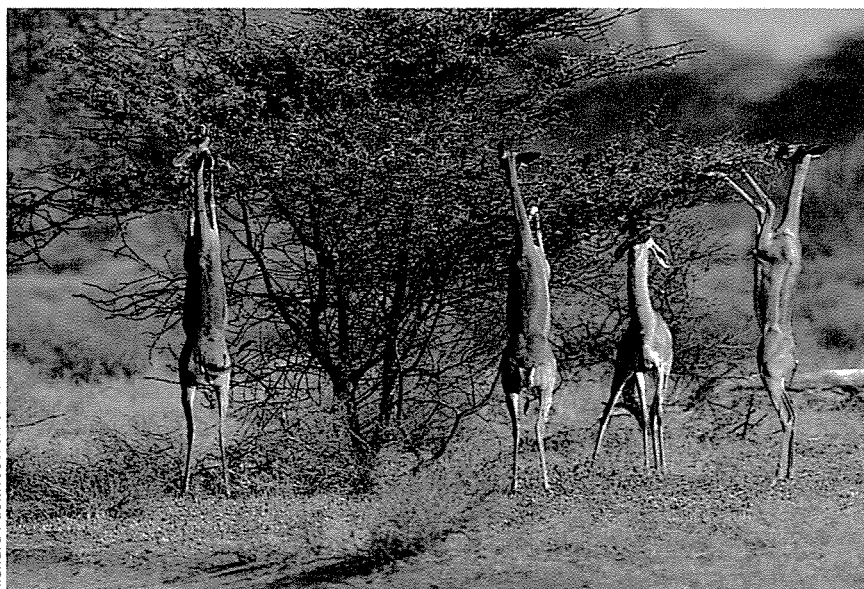
The bee orchid plant has evolved a clever type of mimicry. When a bee tries to mate with the orchid, the bee picks up pollen from the flower and later transfers it to the next flower it mistakes for a bee. So the bee pollinates the orchids without the reward of nectar.

Insects are particularly good at camouflaging themselves for protection against predators. Some look like twigs, others like flowers, seeds, leaves or thorns.

The aye-aye — a Malagasy lemur — has long, thin fingers. It uses the especially slender third digit to pick out wood-boring insects from their holes in trees.

Gerenuks learn to balance on their hind legs to feed on the only available growth. Their necks and limbs have lengthened over the generations.

Tony & Liz Bonford/Survival Anglia



Richard Packwood/Oxford Scientific Films



Paul Raymond



GOING

PLACES



-  MOBILE HOMES
-  MOTOR CARAVANS
-  SAILING BOATS

TODAY MOST PEOPLE HAVE permanent homes, but there are still nomads who travel from place to place, erecting, mooring or parking their mobile homes wherever they choose to stop for a while.

In some regions, nomads use pack animals such as horses or camels to carry their tents. Members of the Bedouin or Tuareg tribes, travelling through the Arabian desert, pitch ridge-pole tents.

Mongolian nomads have two

types of tent: a simple one for over-night stops, and a yurt for longer stays. This has a lattice frame draped with thick felt and is divided into three rooms: one for sleeping (at the back of the tent) and separate day-areas for the women and men. A hole in the roof lets out smoke from the fire.



Moving on

Gypsies are the last true nomads living in Europe today, where their numbers are estimated to be between four and five million. Like holiday nomads (that is, tourists), those Gypsies who still travel live in either a motor caravan or one drawn by a motor vehicle.

The size of motor caravans varies

Never Say Never is a motor yacht with a cruising speed of 30 knots. The weekly hire rate for a luxury yacht such as Parts VI (dining room inset left) could be as much as \$100,000

as much as the fittings inside. A small camper van with living space, engine and controls all situated over four wheels may have one or two sleeping bunks, a simple Calor gas stove, a small fridge and a portable chemical lavatory.

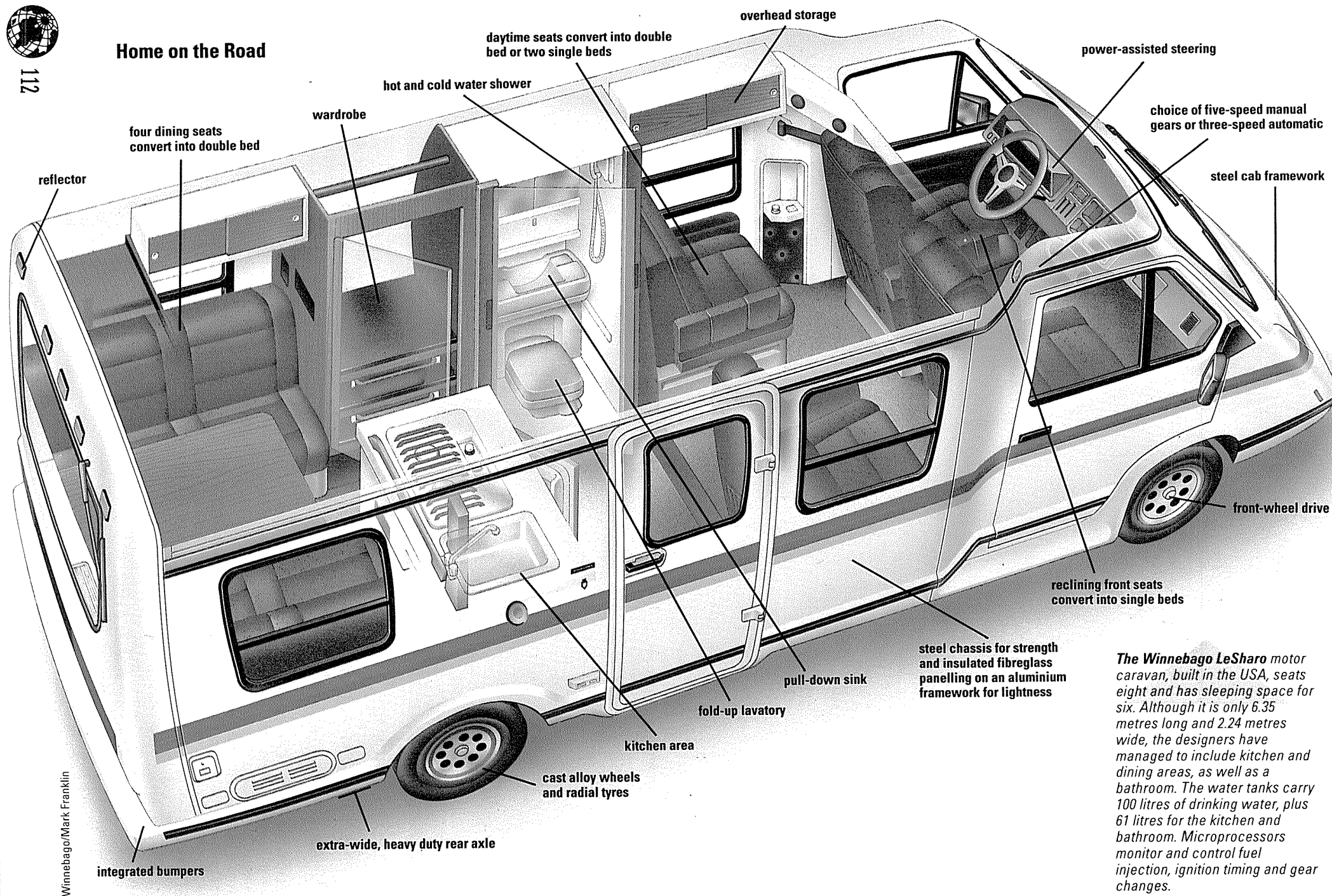
In contrast, there are giant trailers 10 metres long and towed by a powerful motor vehicle. These are designed to cross many hundreds of kilometres of territory, such as the Nullarbor plain of south-west

Jon Bannenberg Ltd





Home on the Road



The Winnebago LeSharo motor caravan, built in the USA, seats eight and has sleeping space for six. Although it is only 6.35 metres long and 2.24 metres wide, the designers have managed to include kitchen and dining areas, as well as a bathroom. The water tanks carry 100 litres of drinking water, plus 61 litres for the kitchen and bathroom. Microprocessors monitor and control fuel injection, ignition timing and gear changes.

SURVIVING SOLO

The long distance sailor's floating home may be small, but it has to hold everything necessary for a voyage that may last months. Tinned food and drinking water are stowed in the bilges at the bottom of the ship. Clothing and small items of gear, such as tools, are kept in water-tight lockers. The sails and anchor are stowed in the peak of the boat. All items not in lockers must be secured in some way. The chart table is surrounded by a rail. Like the ship's compass, the cooking stove is mounted on a system of pivots and rings (called a gimbal) that keeps it level.

Caravan sites may be laid out just like suburbs, with the addition of shared amenities such as shower blocks, a laundrette and even a swimming pool. This site at Bad Feilnbach, near Munich in southern Germany, has room for 750 caravans, spread over 14 hectares.

Australia, without stopping for supplies. There is sleeping space for ten, plus a kitchen, a recreation area, hot water, flush lavatories and a shower unit.

Modern campers may still use tents. Elaborate affairs usually made of cotton fabric and lightweight metal tubing, these frame tents vary from three-sided awnings, which rest against the car or van, to fully enclosed tents with several rooms.

Boat dwellers

Many people who have mobile homes opt to travel by water rather than on land — they live on a boat. A wide variety of flat-bottomed craft is moored along rivers and canals, including the narrowboats once used to carry anything from coal to clay up and down the waterways. Boatmen lived on the barges with their families. Today many have been converted into homes by people who have jobs on the land.

The houseboat in its simplest form can be moved only by towing, but most have inboard or outboard motors at the stern. Houseboats 12 metres long can travel at 50 km an

hour in coastal waters. However, with their shallow draft, high sides and large windows, houseboats are designed for maximum living area — and minimum sea worthiness. At a permanent mooring, a houseboat can often be plugged into mains

Elizabeth II's homes. The *Britannia* is 125.6 metres long — half the length of the liner the *QE2* — 16.7 metres wide, and, running on diesel engines, has a cruising speed of 21 knots. The ship's crew numbers 276, including a 26 piece Royal



Junks cram the harbour of Cheung Chau island, part of the Hong Kong New Territories. Once a base for pirates, Cheung Chau's major industry is now fishing. The fishermen live with their families on the junks. A further 30,000 Hong Kong citizens are boat dwellers, travelling to the shore and back by water-taxi.

electricity and enjoy such services as regular rubbish collections.

On Dal Lake in Srinagar in the Kashmir Valley of Northern India there are over 1300 elaborately decorated houseboats, which are rented out by their owners to tourists. It was the British who first lived on the lake, because they were forbidden to build on the land.

Marine band. The Queen's dining room can seat 56 guests and doubles as a cinema. The ship costs about £10,000 a day to run. There is even a garage for the royal Rolls Royce.

Sea-cruising

Yachts (with or without engines) and cabin cruisers are both equipped so that the crew can live in them for months at a time. Cabin cruisers developed when rowing or sailing vessels were adapted to take an engine, and covered with a roof to create living quarters.

At the top end of the market are the great luxury yachts and cruisers, owned by millionaires and royalty. A famous example is the Royal Yacht *Britannia*, one of Queen

Gypsy caravans of the traditional type, made of wood and horse-drawn, are nowadays rarely seen on the road. Most travelling Gypsies prefer modern caravans towed by motor vehicles.

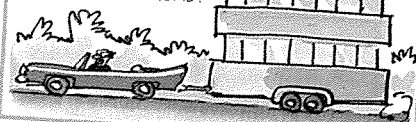
Just amazing!

HAVE WHEELS, WILL TRAVEL

THE WORLD'S BIGGEST MOBILE HOME ON LAND IS THE CUDECOM BUILDING IN BOGOTA,

COLOMBIA — A BLOCK OF FLATS EIGHT STOREYS HIGH. ALL 7,700 TONNES WAS MOVED 28.95

METRES, INTACT, ON 6TH OCTOBER 1974 TO MAKE WAY FOR A ROAD.



Paul Raymonde





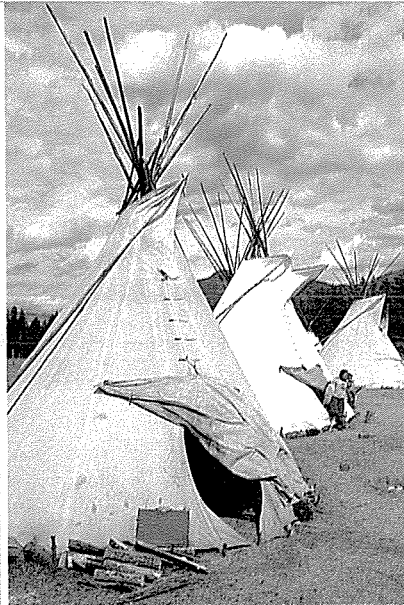
The Hutchinson Library



Bedouins transport dismantled tents to the next camping place in the Arabian desert on the backs of camels.

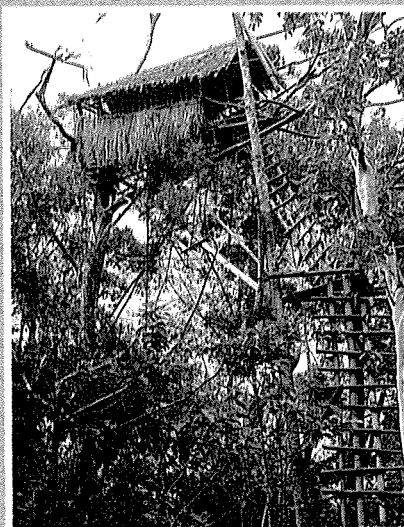
Nomadic Berbers in the Sahara pitch tents woven from sheep's wool and goat's hair.

Tepees nowadays provide homes for only a few native Americans. Animal skins are stitched together and stretched over a cone-shaped wooden frame. Smoke from a fire inside escapes through the top.



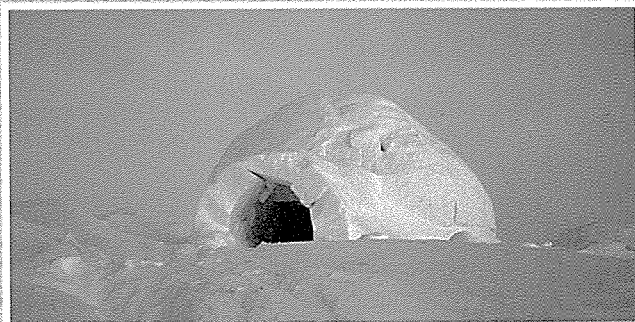
Halle Flygare Photos/Bruce Coleman Ltd

Tree houses are built by the Koriari people of Papua New Guinea, as look-out points, to watch for attacks from neighbouring tribes.



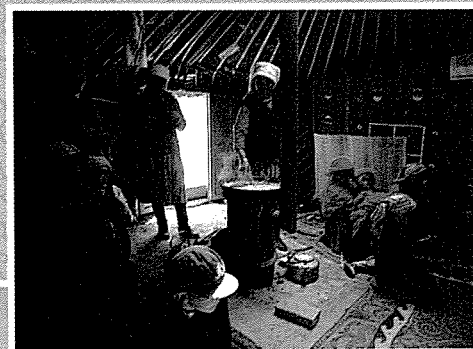
ZEFA

ZEFA



An igloo is the traditional Eskimo winter home. Although made from blocks of ice, the inside can be surprisingly hot, warmed by a burner fed with seal oil.

A yurt is a wooden frame covered with layers of woollen felt. It is a long-stay tent used by nomads in the colder parts of Asia, such as Mongolia.



John Cleare/Mountain Camera



Mud is a popular building material wherever trees are scarce. This mud and grass cabin has been built by Eskimos in the mountains of Alaska.

Spectrum Colour Library

ZEFA

'Cardboard City', in London, Great Britain, is inhabited by homeless people who build shelters out of cardboard boxes. This distressing social problem exists in many of the world's cities.



Sturrock/Network



Q GRIME BUSTERS

Q ULTRASOUND 'SOAP'

Q BIODEGRADABLE FOAM

Detergent bubbles tear apart globules of animal fat below the warm water surface. Detergent action will eventually dissolve the solid fats.

POWER

Paul Brierley

CLEANING

MODERN KNOWLEDGE OF germs and bacteria has led us to understand that cleanliness is essential to health. Much scientific thought has gone into developing domestic cleaning appliances and these are constantly being improved.

Electric showers operate independently of home heating systems to ensure constant hot water for washing. Tumble driers are made to turn off when clothes are dry. Vacuum cleaners are fitted with filters to prevent small dust particles (and some dust mites) being blown back into the room being cleaned.



Invisible guests

Dust mites are microscopic creatures that live in carpets and mattresses and nowhere else. They feed on minute flakes of human skin, which people shed at a rate of tens of thousands of flakes per minute. Mites are sucked up by the vacuum cleaner, but some are blown straight through the dust

filter to land back on the carpet, there to wait for the next meal of skin cells shed as you move around the room!

The vacuum cleaner was invented in 1901 and has changed very little since then. It could be called a mechanical broom — a broom not only sweeps dust along in front of it, but also creates a partial vacuum behind each bristle which sucks dirt along after it.

Machines help with personal hygiene, too. Dirty clothes are loaded into a fully automatic, front-loading washing-machine, a washing programme is selected from the control panel and the machine can be left to do the rest — unsupervised.



Sound method

Ways have been found to make these machines less wasteful of water, detergent and electricity. New models have delay timers built in so that washing can be done at night, when electricity is cheaper. Both washing-machines and dish-

NO SWEAT

Antiperspirant and deodorant are often combined in one product. The former helps to stop perspiration, while the latter destroys or conceals unpleasant smells. Beads of sweat have a negative electric charge. When someone is excited, the surface of their skin becomes positively charged and attracts sweat out of skin pores. Anti-perspirant works by spreading negatively charged flecks of aluminium onto the skin surface to counteract the skin's positive charge. Sweat that is not attracted to the skin's surface dissolves back into the body.

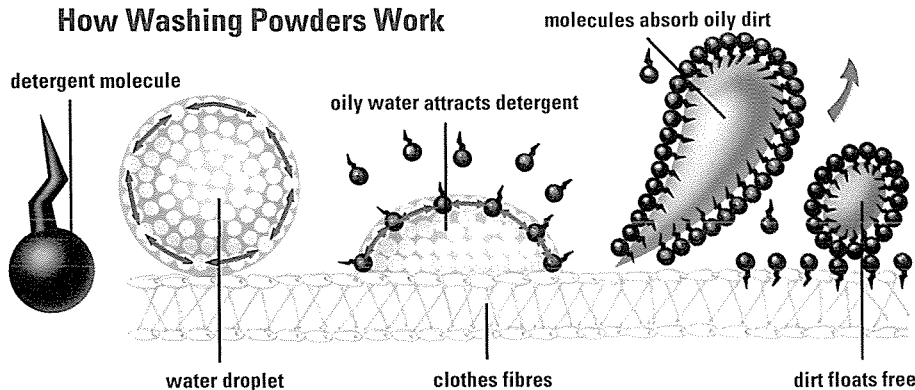
Deodorant is mostly bactericide, which kills bacteria and stops their production of strong-smelling ammonia. Perfume is added to disguise these smells.

washers use many litres of water, often heated to high temperatures, and they require energy to turn the drum or jet the water.

In future, ultrasound promises to provide powerful and more econo-



How Washing Powders Work



Detergent molecules are attracted to oily dirt at the tail and to water at their round end. So detergent traps dirt particles and carries them away from clothes.

added enzymes which help to break down proteins and loosen dirt.

Aside from being effective cleaning agents, it is important that washing powders are 'biodegradable'. Biodegradable foams are those that are broken down natural-

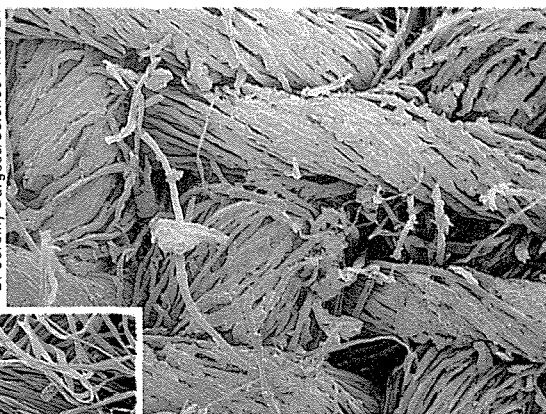
mical cleaning methods. Ultrasound is currently used in industry to clean metal and other components. The objects are immersed in water through which high-frequency sound passes. The rapid vibrations – too quick for the eye to see – shake particles of dirt loose so they can be carried away by a detergent.

Detergents are substances used to aid the cleansing action of water.

Secondly, detergent is an emulsifier, which means it can break up the film of oil that binds dirt particles together. Lastly detergent, having got to the dirt and separated it into dispensable droplets, suspends these droplets in water to be floated away.

Soap is a simple detergent made by reacting animal fats or vegetable

Dr Jeremy Burgess/Science Photo Library



A pure cotton shirt collar (magnified about 16 times) after one day's wear – the woven threads are coated with grease, dirt and skin flakes. The same collar (left), after being washed in an automatic machine, at 50°C.

CHEMICAL PASTE

Peppermint oil, menthol crystals and saccharin are used to disguise the taste of other active ingredients in toothpaste:

water: the main ingredient

chalk: an abrasive to scrape the dirt off your teeth

titanium dioxide: adds a temporary white coating to any yellow remaining

optical whitening dyes: as above

(also commonly used in washing-machine bleach)

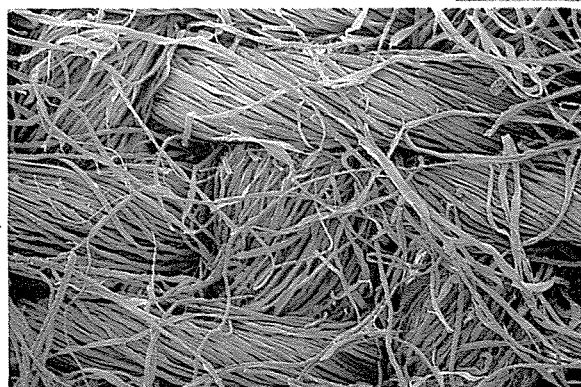
seaweed extract: binds the ingredients together

paraffin oil: for a smoother texture

detergent: makes the toothpaste froth

formaldehyde: a disinfectant to kill bacteria

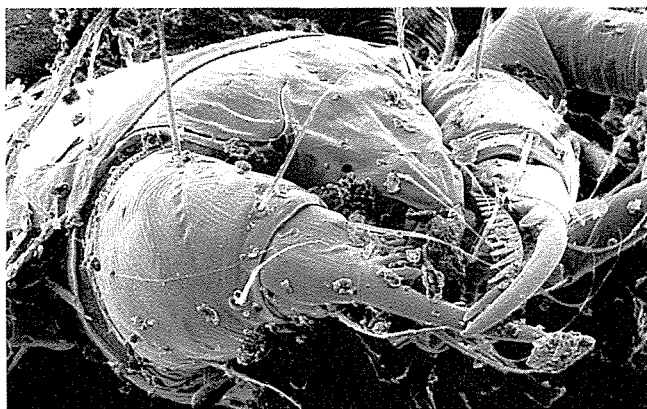
Science Photo Library



oils with sodium hydroxide or potassium hydroxide solution. It was the principal detergent until the 1940s when synthetic or soapless detergents were developed. Synthetic detergents are more effective in hard water, where the soap reacts

ly by the action of bacteria without causing damage to the environment. When flushed into rivers, foams from non-biodegradable powders prevent oxygen dissolving in the water and suffocate river life. In many countries this pollution has been made illegal and the washing powders shown to be responsible have been banned.

Microscopic dust mites live in the home in their millions. Because of their size – this mite is magnified about 1000 times – their existence was not discovered until 1965. Although harmless to most people, dust mites can cause allergies and severe irritation.



Dr Jeremy Burgess/Science Photo Library

They do this in three ways. Firstly they reduce the surface tension of water, allowing objects in the water to become wet. (Surface tension is the tendency of a liquid to behave as though it had a skin, because of the attraction between surface molecules. For example, a drop of water on a greasy surface forms a tight blob, but on a clean surface spreads to wet a much larger area.)

with dissolved calcium and magnesium to form an insoluble scum called lime soap. This is responsible for that 'ring' around the bath. Lime salts also collect as scale on the element of an electric kettle.

Washing-machine powders are soapless detergents with added ingredients to keep down lather, to brighten, to scent or to bleach fabrics. 'Biological' powders have

Just amazing!

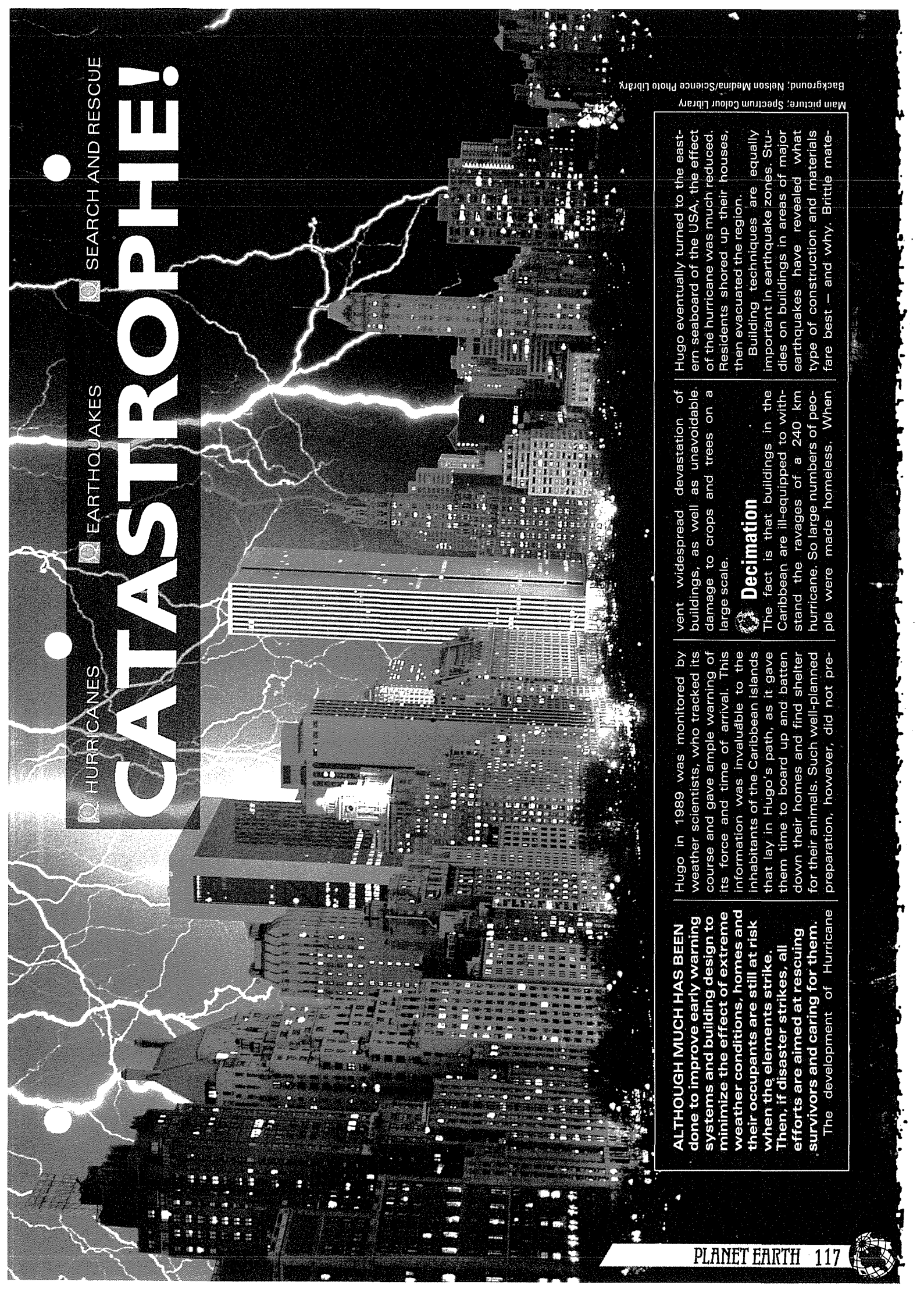
SLEEPING PARTNERS

AN ORDINARY DOUBLE BED IS HOME FOR 2 MILLION DUST MITES – MINUTE CREATURES THAT LIVE OFF TINY FLAKES OF HUMAN SKIN.



Paul Raymonde





HURRICANES

EARTHQUAKES

SEARCH AND RESCUE

CATASTROPHE!

ALTHOUGH MUCH HAS BEEN done to improve early warning systems and building design to minimize the effect of extreme weather conditions, homes and their occupants are still at risk when the elements strike. Then, if disaster strikes, all efforts are aimed at rescuing survivors and caring for them.

The development of Hurricane

Hugo in 1989 was monitored by weather scientists, who tracked its course and gave ample warning of its force and time of arrival. This information was invaluable to the inhabitants of the Caribbean islands that lay in Hugo's path, as it gave them time to board up and batten down their homes and find shelter for their animals. Such well-planned preparation, however, did not pre-

vent widespread devastation of buildings, as well as unavoidable damage to crops and trees on a large scale.



Decimation

The fact is that buildings in the Caribbean are ill-equipped to withstand the ravages of a 240 km hurricane. So large numbers of people were made homeless. When

Hugo eventually turned to the eastern seaboard of the USA, the effect of the hurricane was much reduced. Residents shored up their houses, then evacuated the region.

Building techniques are equally important in earthquake zones. Studies on buildings in areas of major earthquakes have revealed what type of construction and materials fare best – and why. Brittle mate-

Main picture: Spectrum Colour Library

Background: Nelson Medina/Science Photo Library



ZEFA



Without reinforcement, seemingly well-built homes are easily toppled and smashed by hurricane-force gales.

rials, such as bricks and unreinforced concrete, are not a good choice because they can absorb only small amounts of energy before breaking.



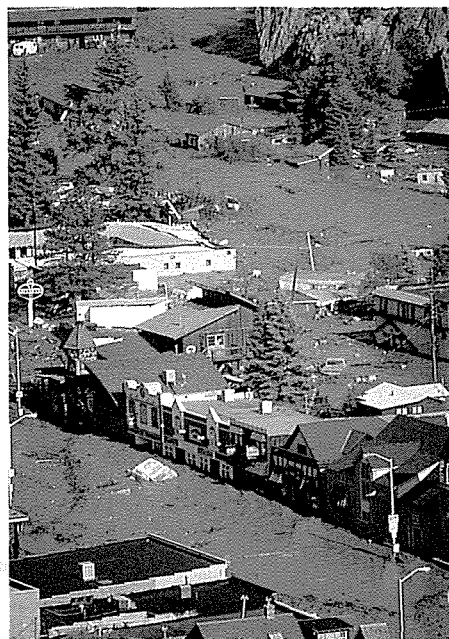
Shock absorbers

Buildings made of steel frames or steel-reinforced concrete, however, survive much better, especially if the internal supports are flexible so they absorb the vibrations unleashed by freak weather conditions. The 17-storey Bank of America building in Managua, Nicaragua, was built on these lines and, unlike most of the buildings around, it

LIGHTNING STRIKES

Lightning strikes the world's tallest structures frequently – the Empire State Building in New York, for example, is struck about 1,000 times a year. Yet such buildings survive undamaged, protected by lightning conductors. These used to be heavy copper wires extending from the highest point down into the ground. Today, they include horizontal strips on upper ledges – all connected to the main vertical conductor. Electric charges in storm clouds above the buildings use them as low-resistance routes to the ground, where they can be safely absorbed.

The damage caused by a broken dam can be long-lasting – the mud that penetrates the structure will ooze out of corners and cupboards for months afterwards.



Kent & Donna Danner/Science Photo Library

MIRACLE BABY

Little Juana Arias has settled down to what can only be described as a second life in Quetzacotl, near Mexico City. She is one of those dozens of babies who survive extensive devastation, while adults around them perish. Eight days after the first of two earthquakes that devastated Mexico City in 1985, Juana, who was just one day old when the earthquake struck, was pulled alive from the rubble of Juarez hospital where she was born. Her mother, also named Juana, died without trace in the same building while having a blood test. Baby Juana, after a thorough medical examination, was adopted by her aunt, Maria Arias, who has two children of her own.

survived the major quake which occurred there in 1972.

The city of Los Angeles, USA, lies near the San Andreas Fault, an unstable region in the Earth's crust where earthquakes often occur. The latest big one was on 17 January 1994, when a quake measuring 6.8 on the Richter Scale shook parts of Los Angeles, bringing down road bridges and killing more than 50 people. The relatively low death toll of this and other quakes in California results largely from the fact that most buildings are now constructed to withstand earthquakes.



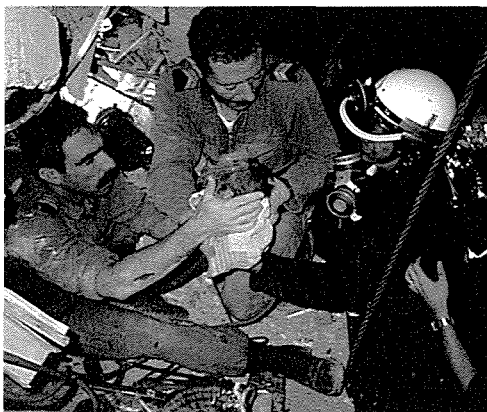
Search and rescue

After an earthquake, there are two immediate priorities: to find anyone still alive and to make safe buildings that have become unstable. Next, plans must be made to provide shelter, food, clean water and medical supplies for survivors.

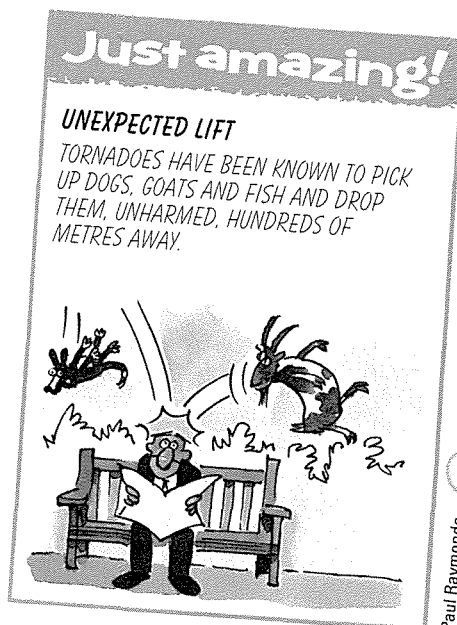
Two main pieces of equipment that help in the search for the living are the Thermal Image Camera (TIC) and the vibraphone. The TIC shows warm objects as white images against black surroundings. It can detect, for example, the hand of a partly buried, living person that would otherwise be difficult to recognise in the rubble.

The TIC cannot usually pick out

someone who is completely buried – and this is where the vibraphone comes in. A vibraphone comprises a headset of earphones and two highly sensitive microphones. It can detect minute sounds – such as someone scratching on debris at depths of 9–10 metres. Where people are less deeply buried, it can even pick up breathing or a heartbeat.



Rex Features Ltd



Paul Raymond



GUERRILLA WARFARE



British Army

The explosion of a car bomb is one of the most dramatic examples of terrorist activity. The car is a perfect vehicle for a bomb. Disguised with high windows, it can be driven to the exact location, yet appear innocuous. Then it can be set off by remote control or booby-trap.

- REVOLUTIONARIES
- TERRORISTS
- BOMB DISPOSAL

GUERRILLA WARFARE HAS been the most common form of conflict since World War II. It is typified by a small-scale war of terror waged against an occupying army, who may often outnumber the guerrillas and have more firepower.

But the guerrillas will have the advantage of knowing the terrain and being able to blend into it. They can strike quickly at selected targets and then 'disappear' out of sight. The longer a campaign goes on, the more support they may get.

The term 'guerrilla' was first applied to the Spanish troops who fought against Napoleon's French armies, and it literally means 'little war'. But the modern definition of a guerrilla is not so clear cut. It depends on your personal point of view whether you categorize a revolutionary as a guerrilla who is fighting for a just cause against an evil regime, or as an evil terrorist attempting to destabilize society.

Beginnings

Guerrilla movements start as small organizations and then attempt to increase their numbers by taking over control of larger and larger areas of countryside. The people are either won over willingly or, if this is not possible, terrorized into submission. One classic example of a small

organization eventually taking over an entire nation is Mao Tse Tung's communists, who eventually gained control over all of China in the 1930s and 1940s.

Guerrilla movements that fail to gain the support of the majority of people and are unable to expand are forced to resort to pure terrorism. The aim is to terrorize the people and the government so that they are forced to give in to their demands.

Some terrorist organizations are prepared to kill indiscriminately in order to achieve more publicity for their political ends. However, this can backfire on the terrorists when public outrage condemns them as cold-blooded murderers.

The Cell System

A terrorist or guerrilla organization in its infancy is small — perhaps only a few hundred members. If it organized itself like a small army, where its members knew each other, there would be a direct link between everybody. So if the authorities were to capture several members of the organisation, they would probably be able to track down nearly everyone else, too.

For this reason, the organization is divided into a number of small groups or 'cells', which are separated from the other cells. Only a few leading members of the organization know who is in each cell, or even who is in some of the cells.

Gamma/Frank Spooner Pictures



Thus, if the authorities infiltrate and destroy one cell, there is no way that they can discover the membership of the other cells — except by starting from scratch.

Guerrillas have adapted their tactics so that they can use their small numbers as an advantage.

Hit and run

They are experts at the 'hit and run' raid, appearing out of nowhere and disappearing into thin air. In jungle warfare, they specialize in ambushes. If a small party of guerrillas chooses the right place, ten men can ambush 100, cause perhaps 50 casualties, then escape into the jungle before the security forces can retaliate.

If, for instance, the ambush is designed so that there is an obstacle — a river or a cliff — between the ambushers and their target, the initial burst of fire is likely to cause considerable casualties. The ambushed will not be able to get at the guerrillas easily and will be too concerned with casualties to extricate themselves. In the ensuing chaos, the guerrillas can withdraw.

Whereas the guerrilla is willing to accept a degree of risk by engaging

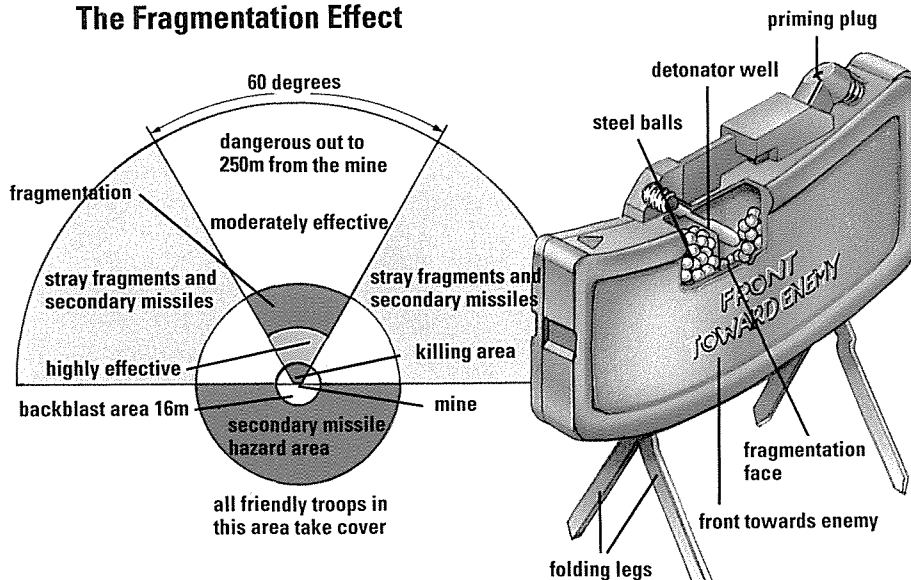


T A Davis/TRH

Mujahideen rebels fought a long guerrilla war against the Soviet army in Afghanistan. The rebels had fewer men or weapons, but used them to great effect.

The Claymore mine can destroy men and machinery. It is not buried but free-standing, and fired by remote control. The fragmentation effect of the steel balls is devastating.

The Fragmentation Effect



The Claymore Anti-Personnel Mine

in battle, terrorists are often described as cowardly because they operate with minimal risks to themselves. The often innocent target, usually unarmed and unprepared, may be attacked by a sniper or by means of a bomb or hijacked in an aircraft. The aim of the terrorist is simply to create terror.

Hijack horror

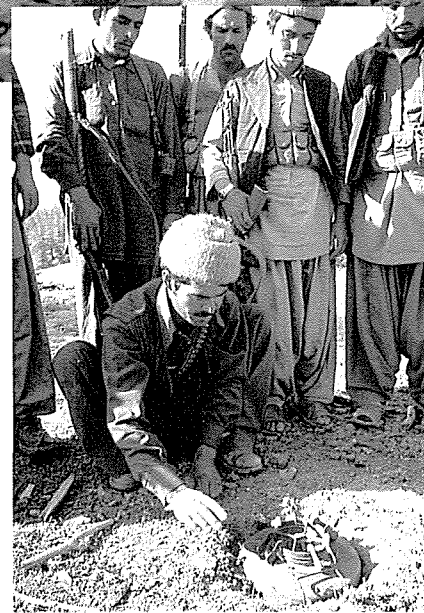
The PLO — Palestinian Liberation Organisation — were the first group to hijack aircraft, in the 1960s, holding passengers and crew to ransom. Since then, this tactic has often been adopted by other groups.

Even more cold-blooded is the bombing of aircraft. The crash at Lockerbie in Scotland in December 1988 is one of the most horrific examples of this tactic.

Terrorist Equipment

Most terrorist organizations are now experts at making bombs. Airports, shopping precincts and hotels are just a few of the public places that have been bombed by groups such as the IRA and the Basque separatist organization ETA.

The nature of terrorist bombs varies according to their target and the skill of the bomber. They may contain commercial explosives or



SOF/TRH

home-made materials and be initiated by remote control, a timing device or a booby trap. One of the most common methods of transporting and placing a bomb is by using a car. This is subsequently detonated by a timer or remote control.

But bomb detection and disposal has developed greatly since the

Just amazing!

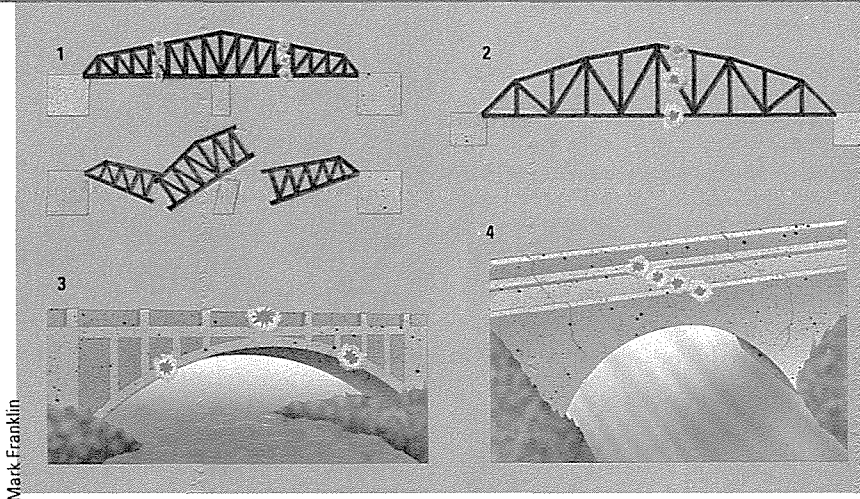
HOLEY REBELS

THE 'HOLY SPIRIT MOVEMENT' IS A REBEL ARMY IN UGANDA INSPIRED BY A WITCH, ALICE LAKWENA. MEMBERS THINK THEY ARE IMMUNE TO BULLETS AND RUN INTO BATTLE ARMED ONLY WITH COLA BOTTLES.



Paul Raymonde

TERRORIST TACTIC – DESTROYING SUPPLY LINES



Mark Franklin

Blowing up bridges is a classic terrorist tactic. Large armies rely on good lines of supply and cutting them off causes great problems.

1 For complicated structures, two sets of cutting charges are used, placed an equal distance from each end.

2 Simple steel bridges are attacked by cutting charges on the beams, crossbraces and floor.

3 For a stone arch bridge, the keystones are blown out with the charges placed as shown.

4 Smaller stone arch structures are easily disabled by using a row of cutting charges across the centre. The explosives used will usually be charges of TNT.

early 1970s. Bomb disposal teams have a variety of detection and disposal aids available to them. Remote controlled vehicles allow the ammunition technical officer (ATO) to remain at a safe distance while he locates a suspected bomb and identifies it by TV camera.

Danger UXB

If he decided that the unexploded bomb is too dangerous to be approached, he can attempt to disarm it using a shotgun to disrupt the firing mechanism. In many cases, however, a manual approach is necessary, either to prevent blast damage or because forensic evidence is required.

Fighting terrorism is about more than defusing bombs. It involves the army, the police and the intelligence services using every possible means to defeat the bomber and the



British Army

The Provisional IRA has been fighting the British Army on the streets of Northern Ireland for over 20 years. To train its troops to deal with situations that may crop up in an urban setting, the Army has built a mock-up of a typical town. The troops can learn how to handle an ambush or other form of terrorist attack.

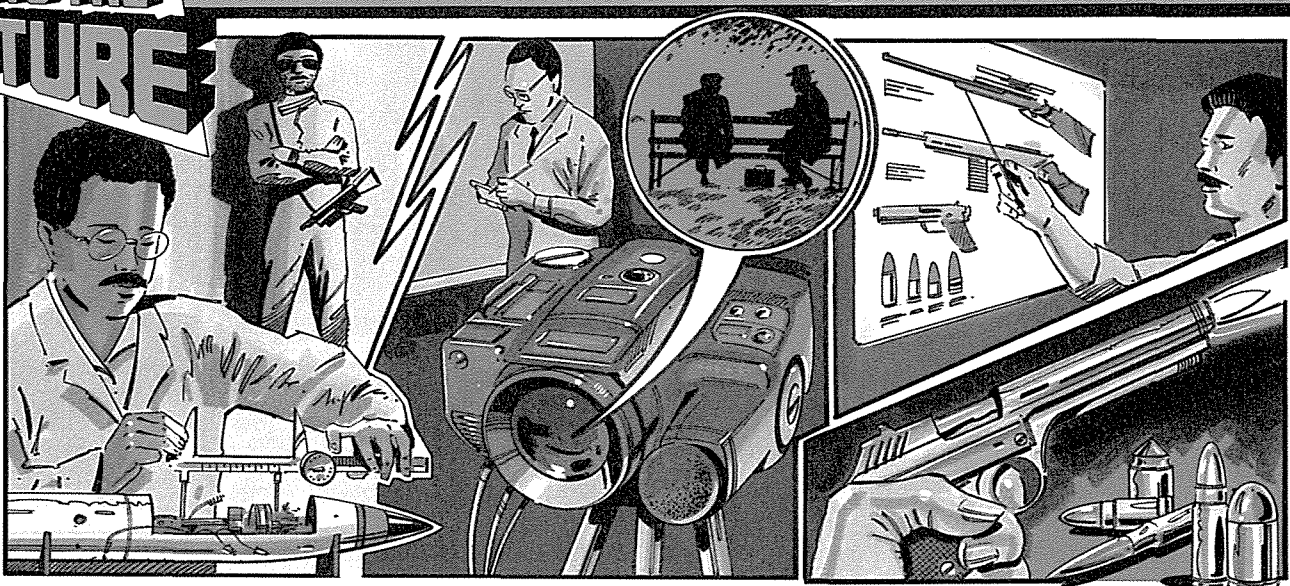
gunman. In a guerrilla war, it can involve all the weapons systems of a modern army including tanks, artillery and aircraft.

A good example is the Irish Republican Army's fight against the

British security forces in Ireland. Although the IRA has only a small number of active terrorists, it has caused mayhem for the combined forces of the British Army and the Royal Ulster Constabulary.

INTO THE FUTURE

ATTACK AND REPRISAL



▲ Terrorists will get more and more sophisticated in their use of electronics and computers, for weapons guidance systems and timing devices.

▲ But the security services will match them step for step, with increased surveillance equipment and ultra-sensitive forensic technology.

▲ A comprehensive catalogue of terrorists and their weapons and ammunition would identify them as soon as a gun was fired or bomb exploded.

Joe Lawrence





Rex Features

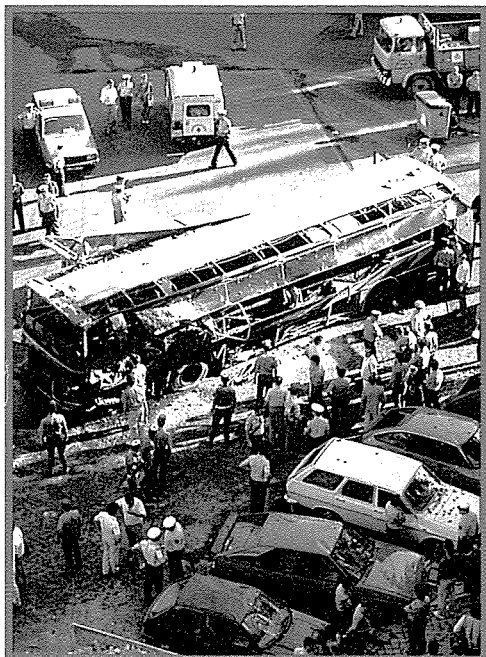
Israeli troops club Palestinian women. The Palestinians have been living in refugee camps in the Gaza Strip and West Bank since 1947, first under Egyptian rule and then under the control of Israel since 1967.

The killing fields of Kampuchea were mass graves for the millions of Khmers murdered by Pol Pot's Khmer Rouge. Executions were carried out on the spot for such 'offences' as falling asleep or being too well-educated.



Rex Features

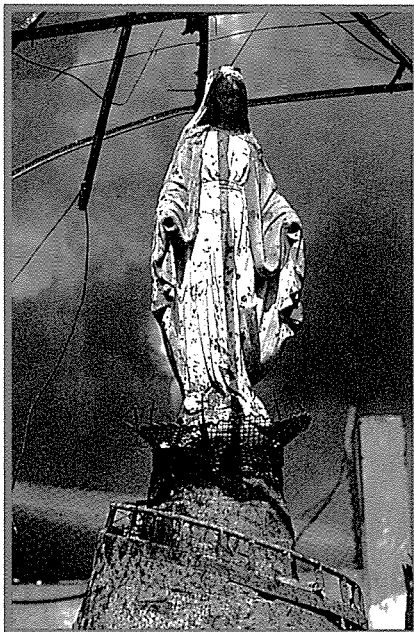
A car bomb in Madrid killed nine police cadets in 1986. It was planted by ETA, the extremist Basque group fighting for independence from Spain.



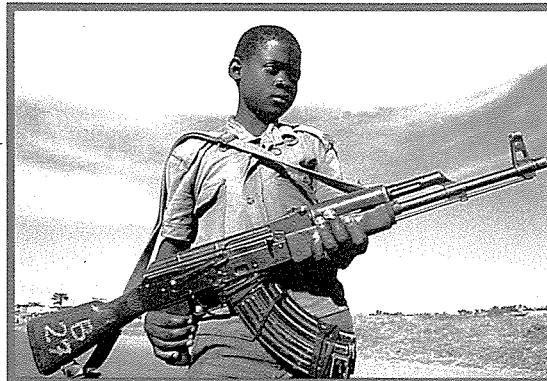
Gamma/Frank Spooner Pictures

Rex Features

Beirut has been a war-zone for over a decade (above). One of the worst attacks came when a truck filled with explosive blew up a US Marine barracks, killing 80 soldiers.



Gamma/Frank Spooner Pictures



Boy soldiers lose their innocence quickly in a war. This member of the Ugandan NRA is barely big enough to hold a Kalashnikov AK-47 assault rifle, but he is ready and willing to kill with it.

Refugees are the innocent victims of war. They are often moved from their homes, to set up camp wherever they can. These Kurdish refugees settled in Turkey after being driven out of Iraq by war.



TRH

Gamma/Frank Spooner Pictures



The Lockerbie air crash claimed 270 lives, when a bomb destroyed a Pan-Am jumbo jet in 1988. Some of the victims were residents of the Scottish town hit by the wreckage. The bomb was thought to have been smuggled aboard in a suitcase.

Gamma Frank Spooner Pictures

Mark Cator/Impact Photos



- EXPLODING EARTH
- MUDSLIDES
- SPEED IN SPACE

NATURE

The power of the sea has always fascinated Man. Its huge waves can be thrilling, as well as destructive.

Gamma/Frank Spooner Pictures

IN ACTION

WHEN THE MOUNT ST Helen's Volcano, USA, erupted in 1980, it sent a hot mass of gas, rock, ash and steam sweeping out across the surrounding area faster than the speed of sound, devastating everything in its path.

No tree within 9 km of the volcano was left standing. Farther away, the blast cloud roared on at speeds of 400 km/h with temperatures up to 360°C. A 130 km/h avalanche, involving 2,800 million cubic metres of the mountainside, followed in its wake. Within minutes, 34 people were dead.

High-speed events in nature may be disastrous, beneficial, or just simply awesome. Some occur with clockwork regularity, while others — like the eruption of Mount Pinatubo, in the Philippines, in 1992 — strike with little or no warning.

Big bang

Probably the greatest explosion in recorded history involved the eruption of Krakatoa, an island situated between Java and Sumatra, in 1883. Rocks were tossed 55 km high and dust fell 5,330 km away 10 days later.

Other materials that spew from a volcano, such as lava and mud,

Submerged by mud the Colombian town of Armero was wiped out in 1985. The mudslide swept over all in its path, killing 23,000 people in the city (inset right).



Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

pour down the mountainside in deadly streams, and may travel for up to 40 km, sometimes at walking pace but sometimes much faster.

On November 13, 1985, a mere hiccup of Columbia's Nevado del Ruiz volcano set in motion a horrific

mudflow. Heat from inside the mountain thawed snow and ice on the steep peak causing a torrent of water that picked up soil and other debris as it rushed down. By the time the flow emerged from a canyon at the base of the mountain it





European Space Agency/SPL

Storm clouds gather over Great Britain. This image of Europe was taken by the European Space Agency's NDA-9 satellite. The clouds show up as white.

A sonic boom is a shock wave caused by an airplane overtaking the speed of sound. It 'passes' its own sound waves and produces the boom we hear.

was 40 metres deep and travelling at 40 km/h. Spreading out across the surrounding plain in an unstoppable slurry, it buried the nearby town of Armero to a depth of 3.5 metres, killing 23,000 people.

Earthquakes, too, can wreak terrible havoc within seconds. In 1985, seismic waves a thousand times more powerful than the atomic bomb that levelled Hiroshima fanned out toward Mexico City in pulses travelling at 25,000 km/h. In the Mexican capital, hundreds of buildings collapsed leaving over 9,000 dead. Deep under the Pacific ocean, water waves generated by the earthquake raced 5,600 km at the speed of a fighter plane to hit the beaches of Hawaii.

Just as the Earth can erupt at terrifying speeds, so the oceans can have fast-changing moods too. The world's strongest currents are those found in the Slingsby Channel off British Columbia in Canada, where the flow rate may reach 30 km/h.

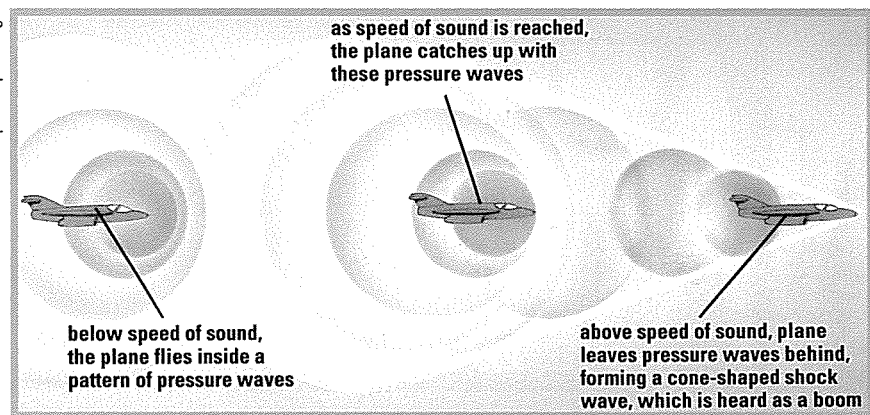
The Earth in Space

Even as you are reading this, you are hurtling through space at a tremendous rate. The Earth spins once around its axis every 24 hours, so that at the equator its rotational speed is 1,669 km/h. As well as this, our planet completes one orbit of the Sun, at an average distance of 150 million km, each year, giving it an orbital speed of 29.8 km/second.

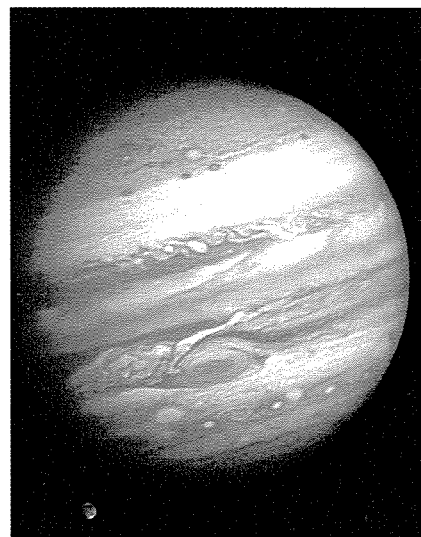
Together with the rest of the solar system, the Sun follows an immense path, 200,000 light-years long, around the centre of the Milky Way Galaxy. Since it takes 'only' 250 million years to do this, our speed through Space is about 240 km/sec!

Fastest planet

The closer an object is to the Sun, the faster it moves in its orbit. Being the innermost planet, at an average distance from the Sun of just 58 million km, Mercury is also the swiftest with an orbital speed of 48 km/sec. At the other extreme, far-away Pluto crawls along at only one-tenth this rate.



John Houghton



NASA/SPL

Comets travel in enormously stretched-out paths around the Sun, which may take them from as little as 0.3 km/sec in deep Space to 550 km/sec nearer the Sun.

The planet that spins around most rapidly on its axis - Jupiter - is also the biggest. Jupiter's 'day' lasts only 9 hours and 50 minutes, while its diameter is an impressive 142,000 km. This means that if you were able to stand at Jupiter's equator you would be whizzed around at 45,500 km/h - 19 times faster than Concorde.

When a massive star has used up its supply of nuclear energy, its outer parts suddenly explode as a supernova. At the same time, the

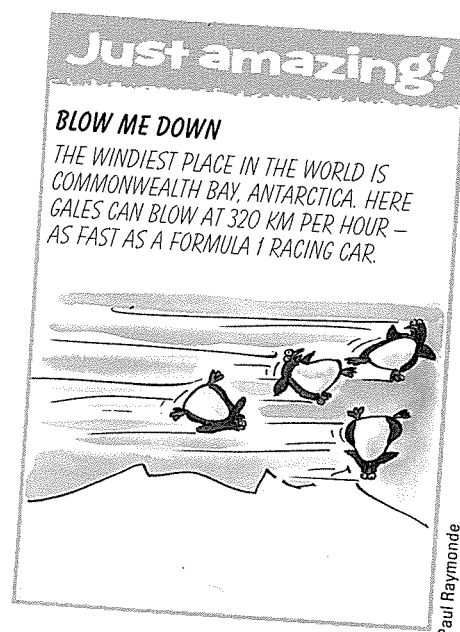
star's Earth-sized inner core, composed of iron, collapses in less than one-fifth of a second to become a dense ball only 25 km across!

The dead core rotates at a much higher speed after it has shrunk and it becomes known as a pulsar. It may be seen with large telescopes because of the narrow beams of light it gives off, like a lighthouse, as it twirls about on its axis. The pulsar left behind after the most recent, nearby supernova - Supernova 1987A - is spinning at the furious rate of 2,000 times every second!

Not only stars, but entire galaxies can also move quickly. Astronomers believe that the universe began in a colossal explosion called the

Big Bang. Even today, clusters of galaxies are still racing apart from one another because of it. The further off a galaxy lies, the faster it rushes away from us. The record is held by a quasar - a galaxy with a very bright centre - known as QSO 0051-279, discovered in 1987.

Jupiter is not only the biggest planet in our solar system, it is also the fastest. Someone standing on its equator would be spinning through Space at 19 times the speed of Concorde.



Paul Raymond



-  THEME PARKS
-  EXOTIC HOLIDAYS
-  SUPER STADIUMS

AWAY DAYS

THEME PARKS NOW ATTRACT more people than all the sports stadiums in the world. Statistics have shown that family-oriented activities are more popular than sports events, so the leisure industry has developed the theme park.

The attraction of a real theme park is that not only buildings, but entire towns can be constructed to create the illusion of another time and place. One such park, the Walt Disney World in Orlando, Florida, is now the world's most popular tourist attraction, with around 30 million visitors a year.

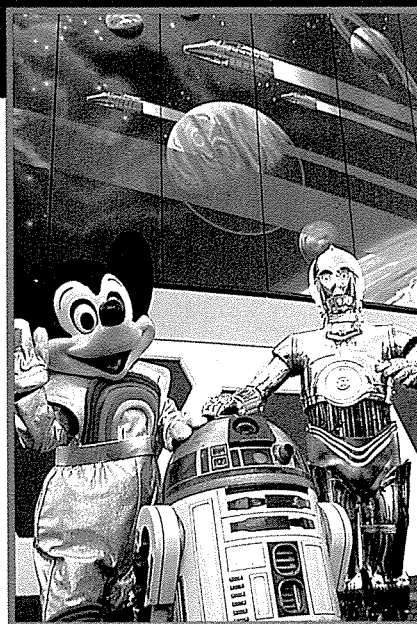
Built on reclaimed Florida swamp-land over an area the size of London, it comprises the Magic King-

dom and Epcot Center, which stands for Experimental Prototype Community of Tomorrow. It borders a lake and contains a cluster of space-age pavilions, each of which represents one of the resources regarded as being of vital importance to the future of mankind — one of them is imagination. Another section, Future World, focuses on scientific achievements.



White knuckle rides

American theme parks are dominated by 'white knuckle' roller-coaster rides, which get more space-age all the time. The special effects experts from Hollywood are used to recreate typhoons, floods and even voyages into Space. The



The Epcot centre at Walt Disney World in Florida, stands for Experimental Prototype Community of Tomorrow.

At Disneyworld you can hob-nob with the stars, such as a space-age Mickey Mouse, as well as R2D2 and C3PO from Star Wars.

Walt Disney company are working with NASA to build a Space Control Mission in Houston, Texas.



Fantasy land

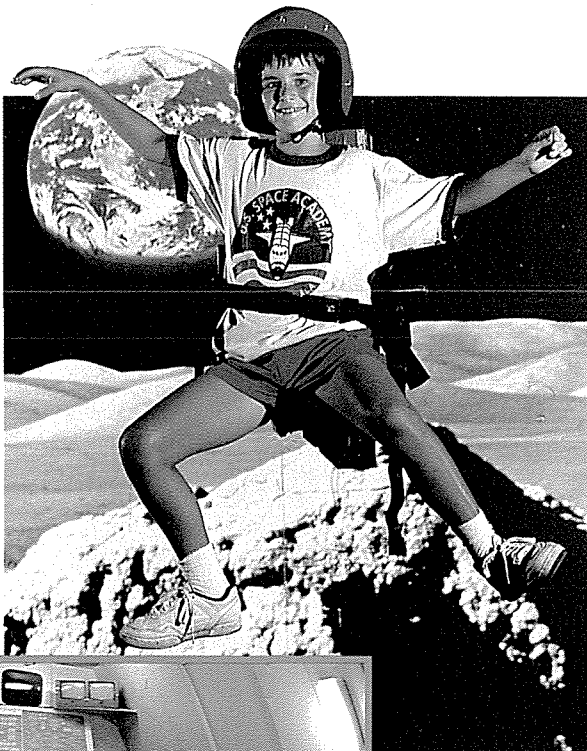
A EuroDisney resort was opened in 1992 just outside Paris and covering an area about a fifth the size of that city. It has five 'lands': Discoveryland, Mainstreet USA, Frontierland, Adventureland and Fantasyland, and six 'themed' hotels to house some of the visitors. Further accommodation in log cabins is provided by the Davy Crockett Ranch about 6 km from EuroDisney in a 'heavily wooded wilderness'.

In its first year, EuroDisney reached its annual target of 11 million visitors, which makes it Euro-

Rex Features



Holidays in Space are almost a reality at the Space Camp, in Alabama, USA. The Microgravity trainer (right) simulates the feeling of weightlessness experienced by astronauts and can give the impression of walking on the Moon. Visitors can also learn what it is like to fly in the Space Shuttle. The centre is run by NASA, and many of the training programmes are the same as those used by real astronauts.



US Space Camp

lasers, holograms and animated robots recreating terrifying scenes from films. For example, you may sit in front of a screen simulating a high-speed drive around a mountain road, and the seats will tilt as you skid around the bends to the sound of screeching tyres. The film may even show other cars plunging down the cliff to create real terror.

In America, one of the most popular holiday destinations for youngsters is the Space Camp in Huntsville, Alabama. Situated on the grounds of the rocket museum next door to the Marshall Space Center where the Saturn V rocket was developed, it offers various entertainments including simulations of space flights.

Children can walk on the Moon, fly the space shuttle, work in zero gravity and live through the experience of being stranded in space. With all the equipment and standards coming from NASA, the week-long courses are not only fun, but also serious science.

Water play

In the 1980s, the leisure industry has come up with the integrated leisure centre, combining a swimming pool, sauna, gym and various entertainment facilities under one roof. The idea is to create a happy mix of activities that meets modern social expectations and finds new ways of spending free time constructively.

Water is important in these estab-

EuroDisneyland has been built just outside Paris. The model was built to show what it would look like with its lands and hotels on its 2,000 hectare site. It opened in April 1992. EuroDisney was the largest construction project in Europe apart from the Channel Tunnel.



Disney

pe's most popular holiday destination. But it ran into financial difficulties, because it failed to make a profit. Reported problems included poor weather, comparatively few overnight stays by visitors, and hostility to the resort by some French people who viewed the enterprise as American 'cultural imperialism'.

The number of leisure centres and theme parks offering a controlled, clean environment is growing all the time. In Britain, old castles and stately homes such as Alton Towers have been turned into theme parks, and plans are afoot to convert the disused Battersea Power station into an ultra-modern centre. But the trend now is to build new theme parks from scratch.

The Walt Disney Company is planning to build a new \$650 million theme park in the United States. It will focus on American history and portray such things as slavery and the civil war. Due to open in 1998, it is designed to cover more than 1,200 hectares, 60 km west of the capital Washington DC, near Manassas, the site of two Civil War battles in 1861 and 1862. The project will also include hotels, with 1,500 rooms, 2,500 homes, golf courses and a 114-ha camping site.

This huge land development project has attracted criticism from some who believe it will lead to increased urbanisation, pollution and extra traffic, and also from historians who fear that it will trivialize American history.

Horror films

The emphasis in the future will be less on roller-coasters and more on

ishments, some of which feature geysers, water cannons, underwater seating, surf-pools, whirlpools, waterfalls, tidal waves and cascades, as well as artificial rainstorms and wave machines. The atmosphere is meant to encourage visitors to relax in the spirit of health and fitness.

A Dutch company, Center Parcs, runs 13 futuristic controlled-



The Center Parcs have controlled environments, so you can swim and sunbathe all the year round in warm weather conditions.

Jules' Undersea Lodge, is 5 fathoms under the sea in Key Largo, Florida, USA. Guests must be qualified SCUBA divers to even reach the front door!

before they are allowed to descend using tethered breathing lines. Once in the Lodge, they are free to do what they want.

Futurism is also catching up with traditional spectator sports. In America, people are now going to sports stadiums to watch television. Massive indoor sports palaces are being constructed to house full-size football pitches in warm, comfortable surroundings featuring restaurants, car parks, central heating and huge television screens.

Super Stadiums

The Astrodome in Houston can seat 60,000 people for a game of American football or 66,000 people for a boxing promotion.

This is nothing compared to the Superdome in New Orleans, which

Robert Holland

Larosey/Jerrican



Gamma/Frank Spooner Pictures

environment holiday villages across northern Europe.

The Centre Parc villages have 7,600 villas and 250 apartments, and each has as its centrepiece an enormous transparent dome containing swimming pools in a semi-tropical environment.

Five fathoms under the sea is Jules' Undersea Lodge, the world's first and only underwater hotel. Built in a



tropical lagoon in Key Largo, Florida, it can accommodate up to six divers in air-conditioned suites that include video, television, stereo, and global communications.

Divers only

The view out of the windows is reported to be unlike any other. So is access to the hotel — guests must be qualified SCUBA divers or obtain a Resort Course Dive Certification

can seat almost 76,000 people and has six television screens measuring 6 by 8 metres suspended from a 68-tonne television rostrum.

Live and on TV

Spectators can watch the game from all possible angles whenever they get bored with the live action in front of them. Not only can they see slow-motion replays of the critical moments in the game, they can also

Just amazing!

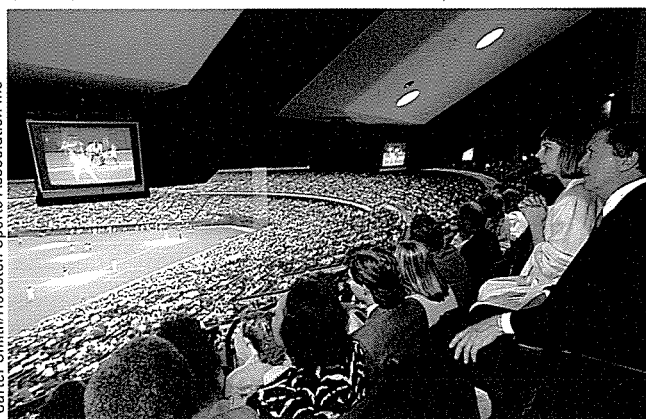
DISNEYFAN

ON 1 SEPTEMBER 1989, CLAUDIA MASSON FROM FRANCE BECAME THE 300 MILLIONTH PERSON TO VISIT DISNEYLAND IN CALIFORNIA SINCE ITS OPENING IN 1955.



Paul Raymonde

F Carter Smith/Houston Sports Association Inc



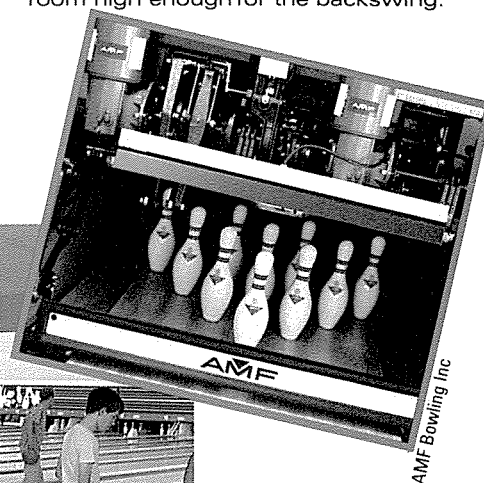
Huge television screens give close-up views and instant action replays at the Houston Astrodome. One of the most modern stadiums in the world, with a covered roof and comfortable seating for around 60,000 spectators, the Astrodome is used for many events.





mium. No more than 15 per cent of Japanese golfers ever play on a real golf course; the rest have to resign themselves to hitting balls at one of Japan's 5,000 driving ranges.

There are even multi-tiered driving ranges to allow more golfers to practise at once. But now a golf simulator called Joytech enables golf-obsessed Japanese to play a game on a video screen in their living room, hitting a tethered ball with a normal club and watching the computer calculate its direction and distance. All that is needed is a room high enough for the backswing.



watch close-ups of their heroes.

The supporters have become accustomed to the advantages offered by these new stadiums. The games are never postponed because of bad weather, and enough of the old stadium atmosphere remains to convince them they are not watching a game on a screen in their living rooms.

Stadium design has been revolutionized in other ways. The Oahu stadium in Hawaii is built on huge hydraulic air cushions, so that the shape of the stands can be changed from a rectangle, for the American football season, to a diamond shape for baseball during the rest of the year.

Indoor golf

A similar trend towards high-tech solutions can be seen in Japan, whose estimated 10 million golfers cannot find enough courses in a country where space is at a pre-

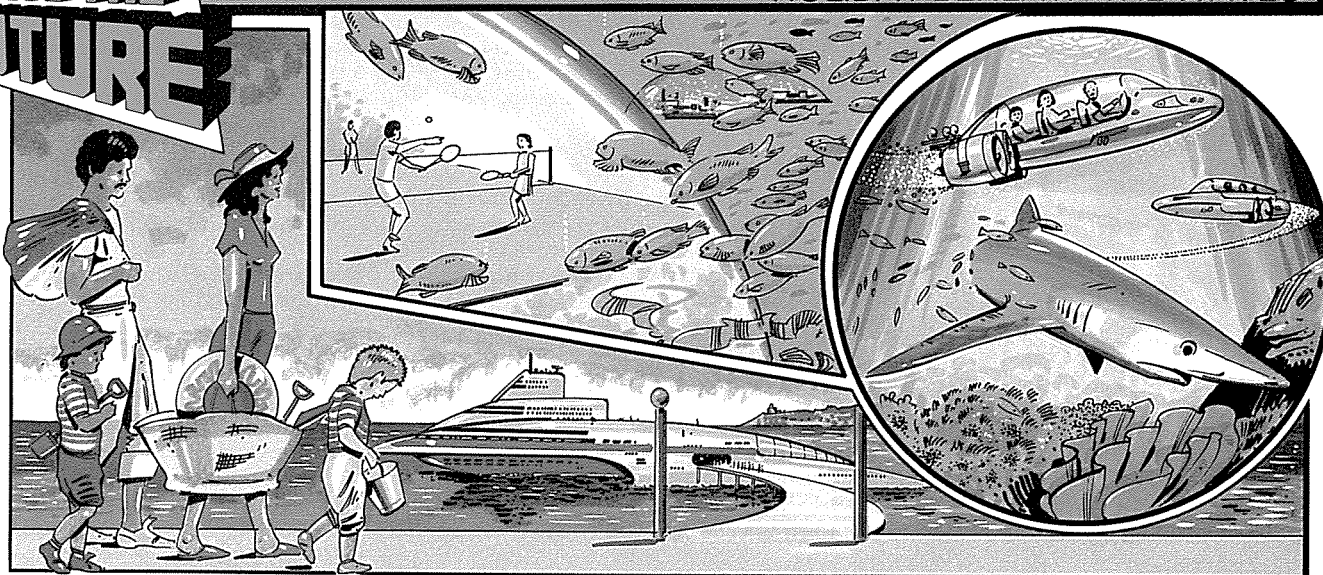
Multi-tiered golf driving ranges are one solution for the great demand for golf facilities in overcrowded Japan.



Ten-pin bowling alleys are popular all over the world. Now they are controlled by computers, from the electronic scoreboards right through to repositioning the 'pins' or skittles (above) and returning the bowling balls.

INTO THE FUTURE

HOLIDAY BENEATH THE WAVES



▲ As land space becomes increasingly congested the family of the future will head for the sea bed – the last 'undiscovered' place on Earth.

▲ Holidaymakers will stay in a vast, heated, pressurized bubble. They will sleep, eat and play games in artificial sun while undersea creatures look on.

▲ The undersea lodge will provide unique opportunities to see and hear weird and wonderful sea creatures living in their natural habitat.



-  HUMAN RESOURCES
-  TEAMWORK
-  MOTIVATION

THE LABOUR FORCE IS THE economic lifblood of the industrialized world. Every day factory workers help produce millions of goods from television sets to toothbrushes to soft toys. The way employers motivate their workers depends on the way they view human nature and behaviour.

Manager X supposes that the average human being has an inherent dislike of work and will avoid it whenever possible. He thinks his workers shun responsibility and have little ambition. Believing that authority is the way to control, manager X dictates orders and threatens his staff with punishment in order to make them work hard.

Management

Manager Y is more forward looking in his attitude. He believes that work is as natural to the average person as is play or rest. He under-

Intensive training, away from the workplace, can be motivating. The employee (below) has been tested on various skills as marked by flags on his jacket.

Spectrum Colour Library

Gamma/Frank Spooner Pictures

WILL TO WORK

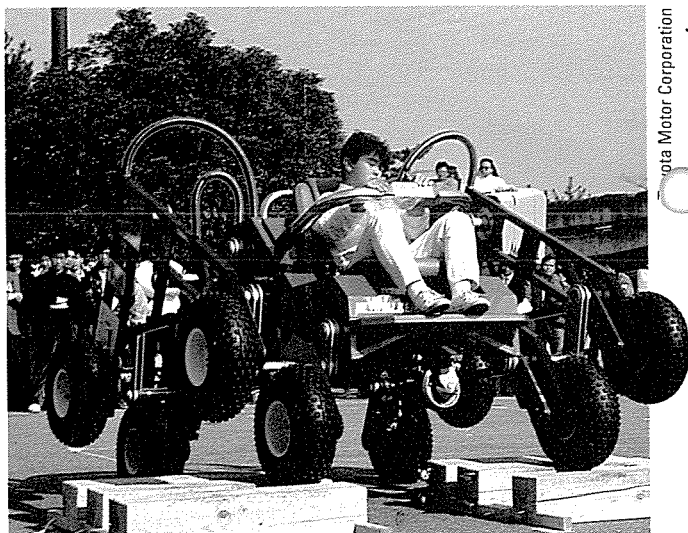


stands that if his workers are committed to their jobs, they will exercise initiative and will seek responsibility. Manager Y's theory is concerned with creating a good relationship between employers and employees. People work hard if they feel their jobs are meaningful, and their managers are supporting them.

Multi-skill training

The Swedish car manufacturers, Saab, are committed to teamwork. At their plant in Malmö, the work-

The Toyota Idea
Olympics are held each year to promote creativity, enhance engineering skills and develop friendship among employees. The brief for this entry was to build a 'sci-fi' vehicle for wild terrain.



Toyota Motor Corporation

Survival games
combine sport, cunning and competition with good fun. These employees are learning to use air pistols that fire paint pellets before beginning manoeuvres.

pay attention to, and train, employees, and to ensure a good standard of service.

The United States is the world's most industrialized nation, accounting for around half of the world's industrialized goods. There is little social distinction in the US between white collar workers (people who work in an office) and blue collar workers (people who work on the factory floor). And workers are encouraged to rise through the ranks from blue collar worker to white collar worker to management.

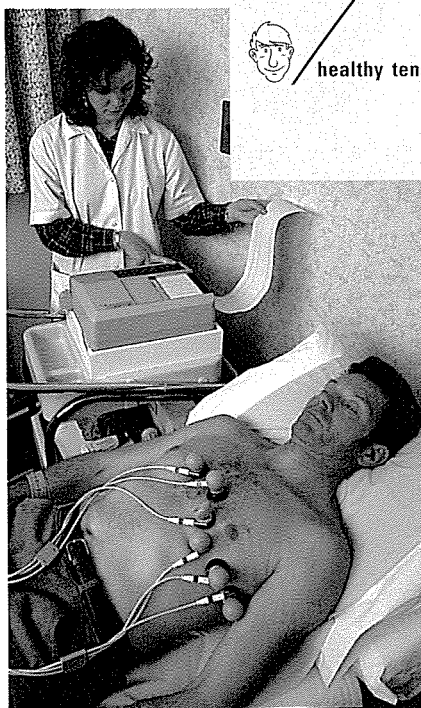
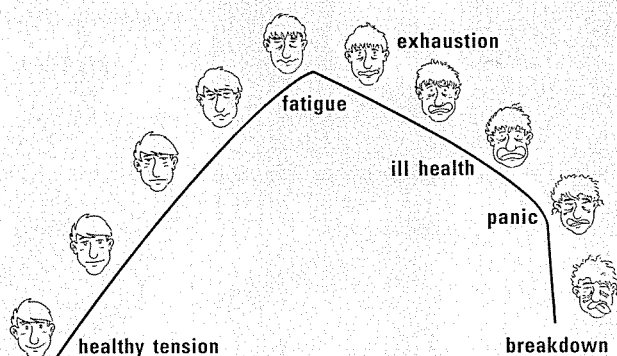
Class system

Japanese work ethics are markedly different to those of the US. Career advancement through rigid class divisions is rare — except when graduate sons of blue collar workers are admitted to management by virtue of their qualifications.

Company loyalty in Japan is common — most people expect to be with one company until they retire. Workers move up the hierarchy automatically as they get older, thus they do not compete with their colleagues for promotion.

Healthy tension
increases work performance, but too much leads to fatigue — and exhaustion. A small amount of extra pressure at this stage can cause mental breakdown. Regular health checks (below) are one way to monitor stress levels.

The Human Function Curve



Simon Fraser/Hexham General/SPL

force is divided into groups of six to twelve workers. Each team member is expected to take his or her turn as group leader — to speak for the others in dealings with management and other groups. Each member is also trained to do the jobs of every other group member.

Winning team

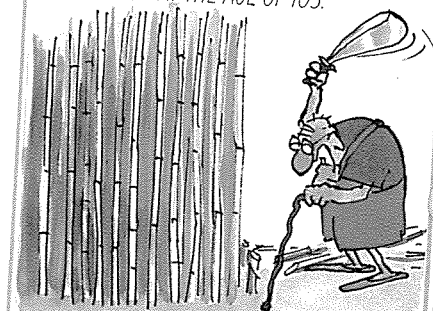
Factory workers in Sweden are viewed as a resource rather than a cost to be reduced with the introduction of new technology.

McDonald's, the American hamburger chain, compares a well-run restaurant to a winning baseball team. All workers are thought of as 'crew members'. Senior managers are encouraged on to the 'field' to

Just amazing!

WORK, WORK, WORK

MR SHIGECHIYO IZUMI FROM JAPAN HAD A WORKING LIFE OF 98 YEARS — THE LONGEST ON RECORD. HE FINALLY RETIRED FROM HIS JOB ON A SUGAR CANE FARM AT THE AGE OF 105.



Paul Raymond





Cleaning oil-polluted beaches is time-consuming and expensive. Volunteers spend months trying to save seabirds (inset, left) and other wildlife.



OIL SPILLS



DISPERSANTS



BOOMS AND SKIMMERS

OPERATION CLEAN-UP

Rex Features Ltd

Norman Myers/Bruce Coleman Ltd

THE WORST OIL SPILL IN American history occurred when the *Exxon Valdez* ran aground off the southern coast of Alaska on 24 March 1989.

Through a gaping hole in the ship's side, 38,000 tonnes of thick, crude oil escaped into Prince William Sound. The slick spread nearly 900 km to the tip of the Alaskan Peninsula and covered 7,800 square km of ocean. As the oil was washed ashore, it wreaked havoc with local wildlife.

In a 1993 report the official death toll included 580,000 sea birds, 5,500 sea otters, and 147 bald eagles.

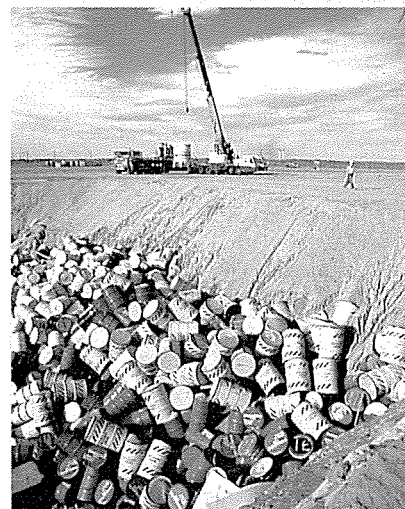
Most of the sea birds that fell victim to the Valdez spill had their feathers coated in oil as they dived into the polluted water in search of fish. Sea otters were even more vulnerable — oil destroys the heat

NUCLEAR WASTE — THE THREAT TO OUR FUTURE

Potentially more dangerous than oil pollution is the radioactive waste from nuclear power stations.

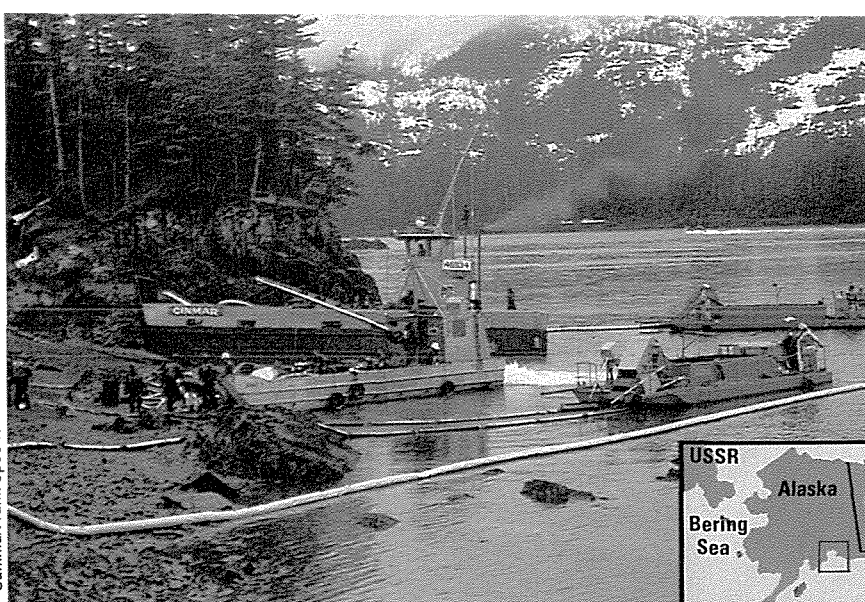
The problem of where to store radioactive material has caused a lot of controversy. In Britain until 1982 some waste with low or medium radioactivity levels, such as reactor components and protective clothing, was dumped at sea. But now 90 per cent of Britain's nuclear waste is buried in landfill sites.

The most highly radioactive waste is stored at the fuel reprocessing plants where it is produced. This waste is encased in lead and concrete and will eventually be stored in a huge system of tunnels, hundreds of metres underground. It will have to remain there for at least 1,000 years before it becomes harmless.



Black Star/Colorific





insulating properties of their fur and, once contaminated, they simply froze to death in the icy sea.

A less obvious but equally catastrophic result of such a disaster is the effect on animals involved in the food chain. For example, bald eagles, feeding on the bodies of sea birds washed ashore from the Alaskan spill, often died from the oil they swallowed. In other cases, an eagle's feathers picked up oil that was then smeared on to its eggs when the bird returned to its nest. As the black tar worked its way through the porous eggshell it killed the growing chick inside.

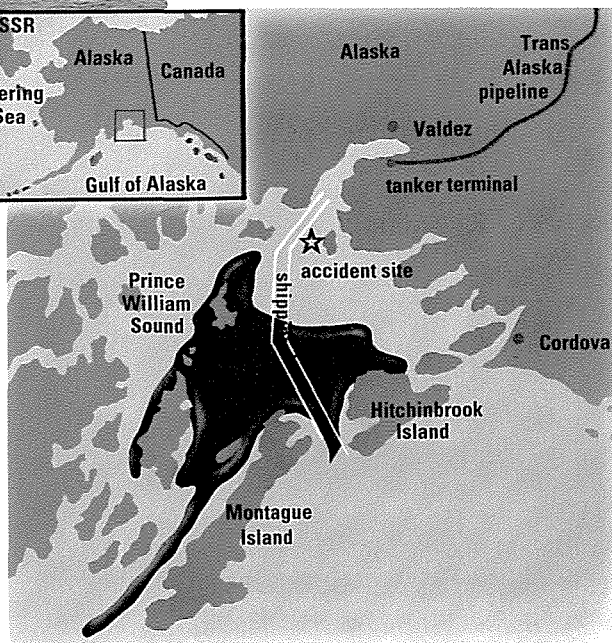
Adding chemicals

Various methods exist for clearing up oil spills, but none is reliable.

About 100 different chemicals, known as dispersants, are available for treating oil spills. Each works in the same way as washing-up liquid – by breaking the oil up into small droplets that are then dispersed by the ocean. To be effective, the dispersants have to be applied almost immediately. Otherwise, as in the case of the Valdez spill, the sea churns the slick into a tar-like emulsion. This 'mousse' responds

Speed is essential in containing an oil spill.

It took 36 hours to surround the Exxon Valdez with booms. By then the oil flow was uncontrollable. Spreading southwest, it eventually reached the tip of the Alaskan Peninsula, 900 km from the wreck. Skimmer boats (above) were sent to clear the oil, but much of the damage was irreparable.



Mark Franklin

WAR ON WASTE



Gamma/Frank Spooner Pictures

Accidents involving toxic chemicals have become so frequent in America that emergency response teams have been set up (above). Trained to work in protective suits complete with breathing apparatus, the teams must reduce the danger as quickly as possible after a spillage. Often, whole communities have to be evacuated.

Oil spillages are not the only cause of pollution on beaches. Long stretches of coastline can be devastated by toxic waste from factories. This beach in South Humber, Britain has been stained red by iron ore deposits from a chemical plant.

the slick to make it give off a dense cloud of vapour, then a sudden, intense pulse from a second laser will cause the vapour to ignite.

A third approach is to surround and skim off the oil. Booms are large, fireproof tubes that confine a slick while skimmers scoop the oil out of the water. The trouble with this method is that oil seeps under the boom if the water current flows slowly, at a rate of 1 km/h or less. High winds and waves cause the oil to slop over the top of the boom.

Superbugs

In the future, it may be possible to release 'superbugs' – micro-organisms that have been genetically engineered to feed on oil and break it down into harmless substances. Artificial lifeforms such as these will have to be carefully monitored and controlled in case they affect the delicate balance of life in the sea.

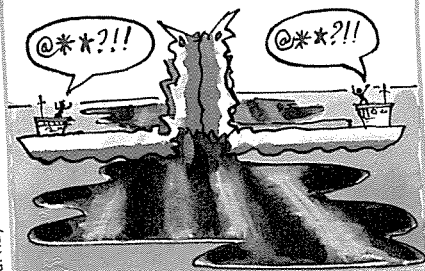


Bob Edwards/Science Photo Library

Just amazing!

WHAT A WASTE!

THE WORLD'S LARGEST OIL SPILLAGE OCCURRED WHEN TWO SUPERTANKERS COLLIDED OFF TOBAGO ON 19TH JUNE 1979, SPEWING OUT 300 TONNES OF CRUDE OIL – ENOUGH TO HEAT AN AVERAGE HOUSE FOR 90,000 YEARS.



Paul Raymond

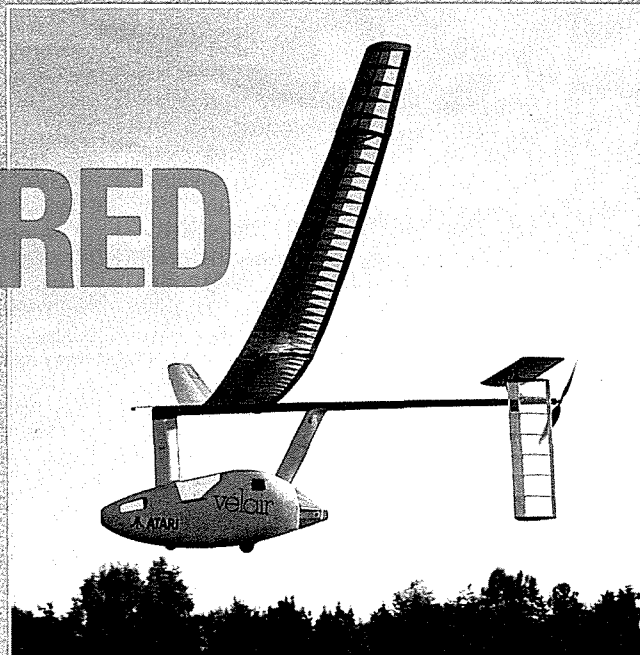




Man's dream of flight comes true in Birdy – thanks to movie special effects.

Today Man really can fly – using technology and by harnessing old-fashioned leg power.

MAN-POWERED FLIGHT



TO FLY LIKE A BIRD IS A dream that stretches back to antiquity. But only recently, after the development of jet engines and Space travel, has man-powered flight become possible.

In 1959, the British industrialist Henry Kremer offered a prize of £5,000 to the first entrant to fly an aircraft round a one-mile, figure-of-eight course using muscle power alone. Eighteen years later, the Kremer prize – now increased to £50,000 – was won by Paul MacCready and Peter Lissaman with their lightweight plane, Gossamer Condor.

The designers worked out that a machine the same weight as a hang-glider, but with a wing area three

times bigger, could just about be kept airborne by a fit athlete. The pilot would sit in a streamlined cockpit and pedal hard to keep a large propeller slowly turning. Long, narrow wings, spanning almost 30 metres, would give the aircraft excellent lift and allow it to cruise at speeds as low as 16 km/h without stalling.

● Aerodynamics

The ability to fly slowly is essential in a man-powered plane because the drag, or air resistance, on the craft grows rapidly with increasing speed. Beyond a certain point, the drag is so great that no amount of pedalling by the pilot will make the machine fly. The need for low speed, in turn, dictates the width and area of the wings.

There are various ways a man-powered aircraft can be made to fly, including flapping its wings like a bird or using jets of compressed air. But the best way of transforming the mechanical power generated by the pilot's legs into a forward thrust is with a propeller. This must be large enough to push sufficient air back so that the plane is driven forward and kept airborne without making the plane too heavy.

● Design

Weight is the single most important factor in the design of a man-powered aircraft. Every component must be as light as possible and yet have the strength to withstand the forces acting on it during flight. For the Gossamer Condor the designers

Peter F Selinger





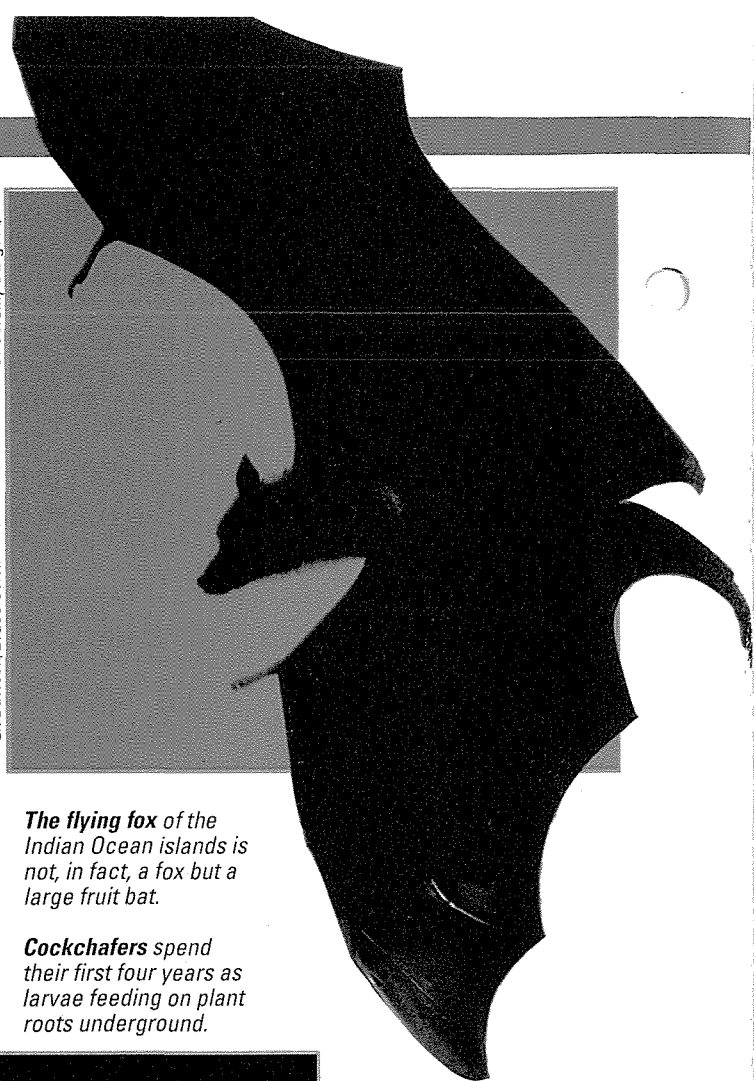
Catkins of the alder tree are free swinging arrangements of uni-sexual flowers. Catkins are designed to catch the wind and so spread the pollen from their flowers over a wide area.



Dr Jeremy Burgess/SPL

Four-winged flying fish skim the surface of the Red Sea, beating the lower part of their tails in the water up to 50 times per second. They reach speeds of over 60 km/h before rising into the air. One has been observed to remain airborne for 90 seconds, travelling a distance of 1109 metres.

LR Dawson/Bruce Coleman Ltd

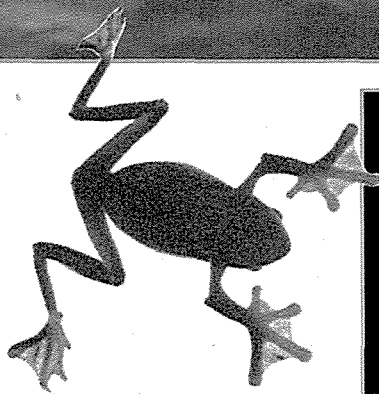


The flying fox of the Indian Ocean islands is not, in fact, a fox but a large fruit bat.

Cockchafer spend their first four years as larvae feeding on plant roots underground.

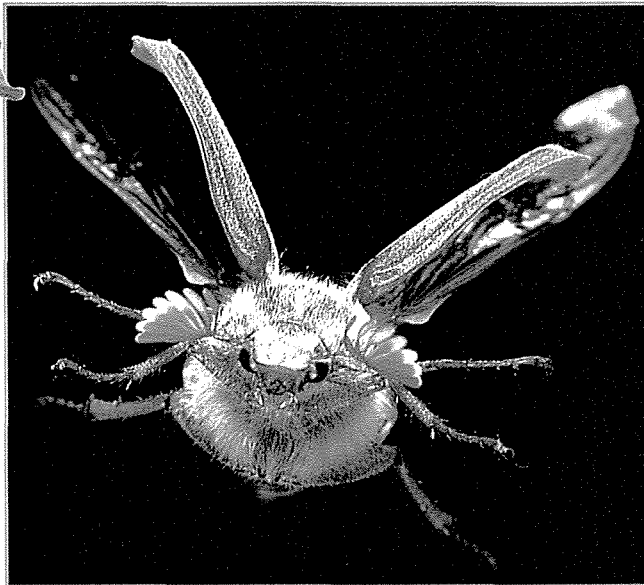


A Warren/Ardea London



Flying frogs do not actually 'fly' – they use their webbed feet to glide between trees and break their fall to the ground.

A dragonfly begins life under water as a larva. When fully grown, it crawls up a stem and sheds its skin. Blood then pumps into its wings to expand them.



Alain Compost/Bruce Coleman Ltd

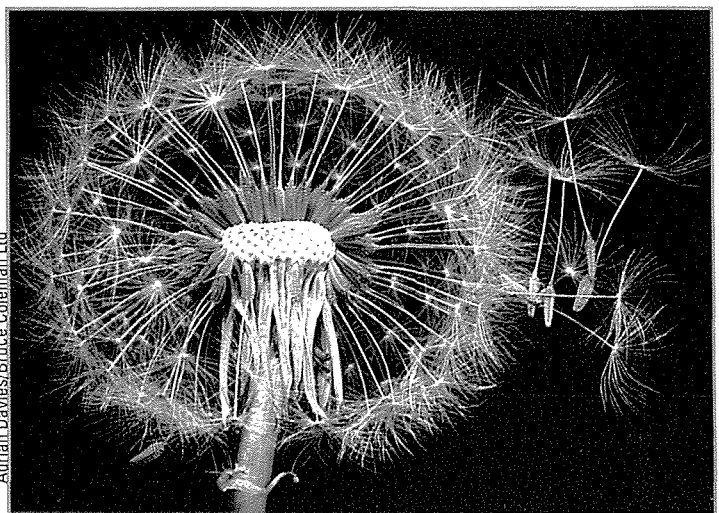


The flying lizard glides by opening membranes supported by ribs.

Plumed seeds of the dandelion weed can be carried hundreds of kilometres by wind.



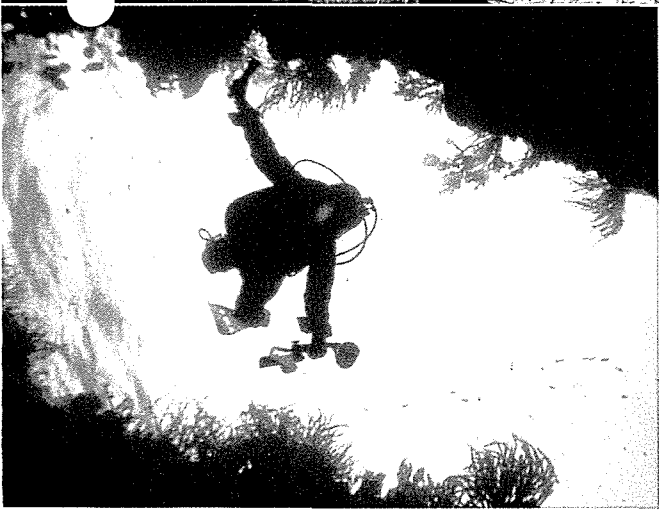
Stephen Dalton/NHPA



Adrian Davies/Bruce Coleman Ltd

STRANGE WORLDS

Rob Palmer



***Mammoth Cave** in the USA, consists of a seemingly endless labyrinth of chambers, making it the longest cave in the world. The Blue Holes in the Bahamas (inset) were once above sea level but are now submerged.*

There are still parts of Planet Earth that remain unconquered. They include mountain ranges, vast deserts, the ocean depths and dense rainforests. Man's failure to make inroads into these areas has ensured the survival of many unique species of plantlife

These hidden, isolated corners of the world are largely unexplored because man is unable to overcome physical barriers to reach them.

On top of Mount Everest – at 8,848 metres, the world's highest peak – temperatures can fall to -36°C and winds can reach speeds of 240 km/h. It is almost impossible to move about without breathing apparatus, though since it was first climbed in 1953, some climbers have actually reached the summit without the use of bottled oxygen.

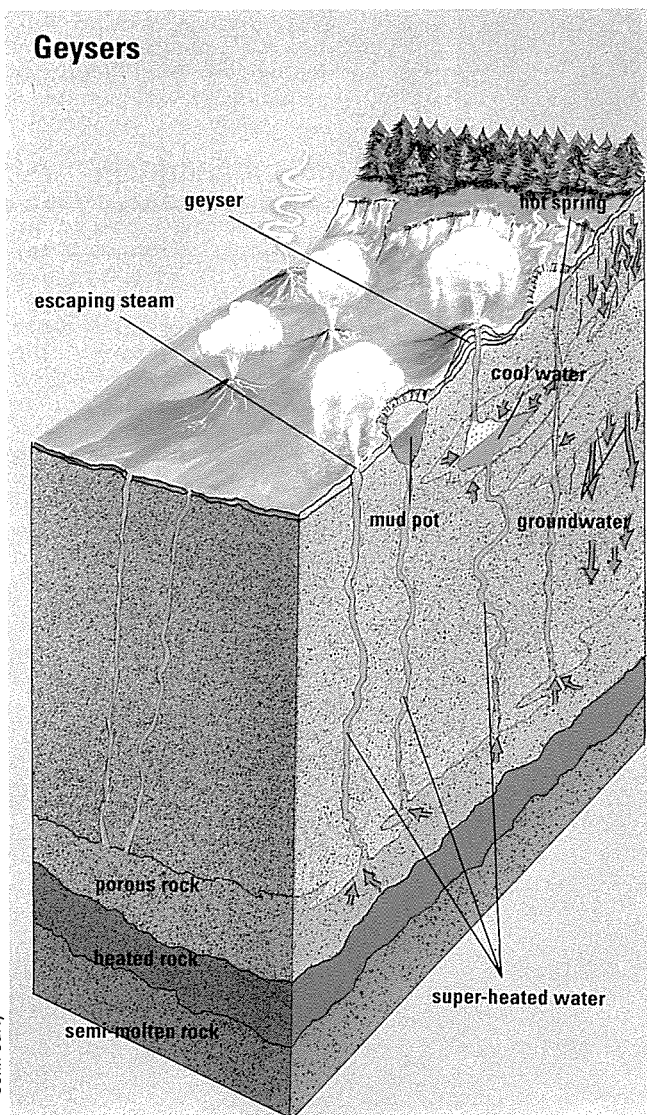
Mountains make up about 5 per cent of the Earth's land mass. The major mountain ranges include the

Rockies and Andes of America, the Alps and Pyrenees of Europe, the Atlas Mountains of North Africa and the Himalayas of central Asia. In each range there are tracts of land hundreds of square kilometres in area that remain isolated due to their difficult terrain and climate. Except in warm regions, very high ground is permanently covered in snow. Lower down, even where there is access by road, rail or air, communication links are cut off for much of the year by



Geysers

John Carty



Geysers are formed by superheated water rising into pockets of groundwater. A small amount of water reaches boiling point and the resultant steam rises to the surface, taking some of the water with it.

turbs them. Insects carry micro-organisms which, if introduced into the body, cause serious diseases such as sleeping sickness and malaria.

Harsh climate is the reason why the Arctic and Antarctic still remain

largely unconquered. These are vast areas of permanent ice, snow and cold waters. Even in summer the temperature rises to only about 8°C above freezing and can fall to -50°C. Frostbite is a constant danger.

The Antarctic ice sheet comprises nine-tenths of the world's supply of fresh water. Since its discovery in 1820, explorers have battled against sub-zero temperatures, raging snowstorms and icy crevices to chart Antarctica's frozen wastes. Covering an area about 14,245,000 sq km, the frozen continent is larger than any country in the world except Russia. The average temperature in one area is -57°C. Winds can reach 300 km/h.

Geoff Renner/Robert Harding Picture Library

Loose snow, crevices, glaciers and steep slopes make journeys across these frozen wastes very difficult. Sledges or caterpillar-track vehicles must be used. Food and fuel have to be transported, hampering progress. For prolonged stays or treks, permanent camps must be established and provisions brought in by boat or plane.

Icy wastes

The Arctic is an area of frozen ocean surrounded by large masses of land. Waters around the ice-cap freeze in winter, then thaw in the spring. It is impossible to predict when and where the ice will break up, so one cannot make any fixed settlements on the edge of the ice cap. The Antarctic is a mass of land permanently buried beneath a great sheet of ice. Here, countries such as Australia, Norway, Britain and Chile have established settlements. But people usually spend only a few months there at a time.

THE AMAZON

The Amazon - 6,500 km long - is the world's second longest river after the Nile. It cuts through some of the most inhospitable and inaccessible territory on Earth. On its long journey to the sea, the Amazon varies in colour. High in the Andes, near its source, heavy loads of mud and silt make the water black. In contrast, some of its tributaries have crystal-clear water and are called the white rivers - rios blancos. Both white and black streams flow side by side for several miles in separate currents at Manaus, where the Rio Negro flows into the muddy Amazon.



Tony Waltham



■ REPRODUCTION

■ RESIDENT ALGAE

■ REEF SQUADS

CORAL REEFS

REEFS ARE THE ONLY MAJOR geological feature on this planet that are not created by wind and rain and the huge forces of nature. These vast structures, that can grow to over 2000 km in length, are built chiefly by small animals - coral polyps.

The Great Barrier Reef is the world's biggest, covering over 200,000 sq km off the north-east coast of Australia. It consists of thousands of smaller reefs, and islands, many of which are covered at high tide. Reefs are made of limestone formed from the skeletons of billions of individual dead coral. Coral polyps are the living part of

the reef. The term 'polyp' describes an animal with many arms or tentacles. Coral polyps look like small underwater flowers - similar in appearance to sea anemones. In fact, both corals and sea anemones are animals that eat other tiny animals: zooplankton - the floating and drifting animal life of the oceans. Coral polyps have sack-like bodies

and mouths that are surrounded by rings of tentacles. The animals, measuring 25 mm - 1 cm in length, stay protected during the day in indentations in the external limestone skeleton of their coral.

● Tentacles

At night, when food is plentiful, they blossom like flowers - their tentacles shoot out stinging threads that paralyse and kill the tiny animal plankton that floats by. Hours on the tentacles then set

Carl Roesler/Bruce Coleman Ltd

A polyp is the living part of a coral reef. Polyps build reefs by incorporating the mineral calcium carbonate from the surrounding water into their external skeletons.



that it is not drawn back into the sponge.

The abundance of plankton and the huge colonies of plants and animals living on the reef attract great shoals of predatory fish – there are over 1,400 species of fish on the Great Barrier Reef alone.

Predators and prey

In the 'garden' of coral, near the surface where the reef is growing, the fish are brightly coloured. The parrot fish, for instance, is garishly coloured

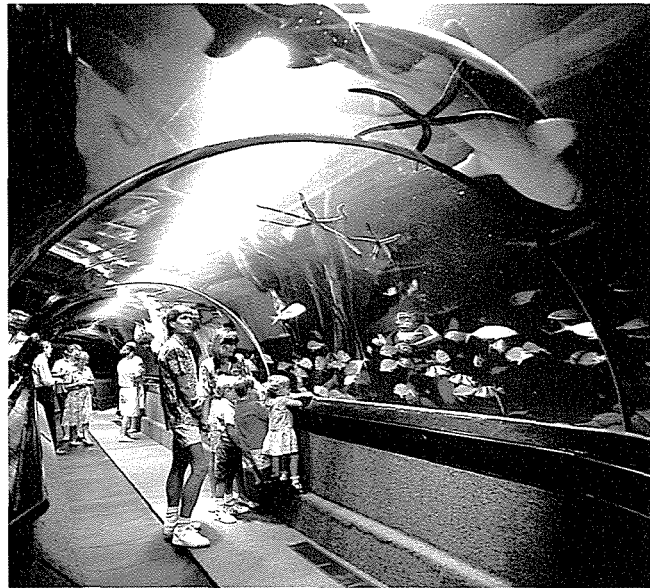
Shell collecting is being restricted along areas of the Great Barrier Reef.

Because of an increase in visitors not only is coral being damaged but rare species of fish and other wildlife – often specific to a reef area – are in danger of being wiped out.



Warren Williams/Planet Earth Pictures

Underwater World is built below sea level, amid Australia's shark-infested Great Barrier Reef. It is possible to walk through its 80 metres of tunnel separated from the coral and sealife by only 6 cm of transparent, tough acrylic.



Underwater World, Queensland

in reds, greens, yellows and blues. It has a powerful beak that it uses to crunch open coral. The butterfly fish – also brightly coloured – has a long snout that it uses to reach inside the limestone casing to pick out polyps. Coral gardens are so overpopulated that several creatures may share the same cracks or crevices. At dusk, big-eyed night-time feeders like the spiny squirrel-fish and the dainty red cardinal leave the protection of their homes, while the angel, butterfly and

surgeon fish move in. Cracks in the reef offer protection from sharks, barracuda and groupers that can weigh up to 270 kg and have mouths huge enough, it is said, to be able to swallow a diver whole. But the moray eel can prise out prey that is jammed fast in a fissure. It seizes its prey with its powerful teeth, then knots its tail outside the entrance of the crack. It contracts its muscles, bracing itself on the knot and pulls even the most stubborn fish free.

Reef destruction

The ecosystem of the Great Barrier Reef – like those of other reefs – is under threat. Not just from the oil tankers that occasionally run into it, spilling their cargoes. Oil companies have already drilled several test wells into the reef in the hope of finding oil there. Other mining companies are eager to mine the limestone that forms the basis of the reef to use in cement and fertilizer.

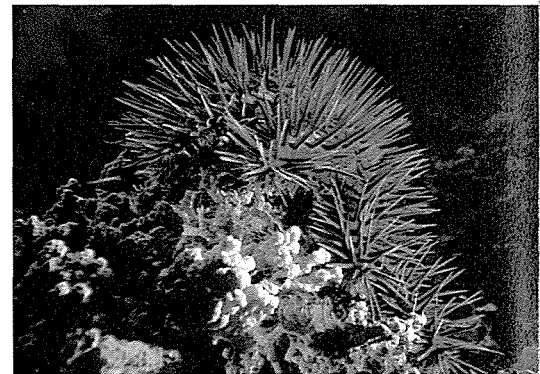
Ornaments

The increasing number of visitors to the reef is threatening the ecological balance, by shell collecting and spear fishing, which now are restricted. The Marine Conservation Society is monitoring the destruction of the reefs and trying to stop the trading of corals, shells and other reef animals.

The development of the coastline inshore from the reef is also causing problems. Fertilizers and insecticides

used in agriculture are washed down the rivers and get into the reef's vital food chain. Industrial pollutants are pouring into the sea and building work has produced mud that is silting up the reef's lagoons. New and expanding towns pump raw sewage directly into the sea, disrupting the ecological balance. Coral polyps are particularly vulnerable to sediment and pollution. Without urgent conservation the world's coral reefs may be the first major element of the marine ecosystem to be destroyed.

CORAL KILLER



Pete Atkinson/Planet Earth Pictures

A recent epidemic of crown of thorns starfish is threatening large areas of the Great Barrier Reef. Feeding on coral polyps, one adult starfish can clear up to 150 sq cm of branched coral per day. The starfish tend to attack in groups, swarming across a reef in a feeding frenzy and killing it completely.

A crown of thorns starfish has up to 23 arms and can grow to 70 cm. Its upper surface is covered with spines containing a venom that causes pain and vomiting in humans. To control their numbers, these starfish must either be collected by hand (using thick gloves) and disposed of on land or be injected with a poison that can be absorbed safely in the marine environment. Both these methods are expensive and labour-intensive.

Just amazing!

LIVING ROCK

THE GREAT BARRIER REEF IS THE BIGGEST STRUCTURE MADE BY LIVING ORGANISMS – 2028 KM LONG – AND HAS TAKEN SOME 25,000,000 YEARS TO GROW.



Paul Raymond



COURSE GRADIENTS

SLALOM SKILLS

ELECTRONIC TIMERS

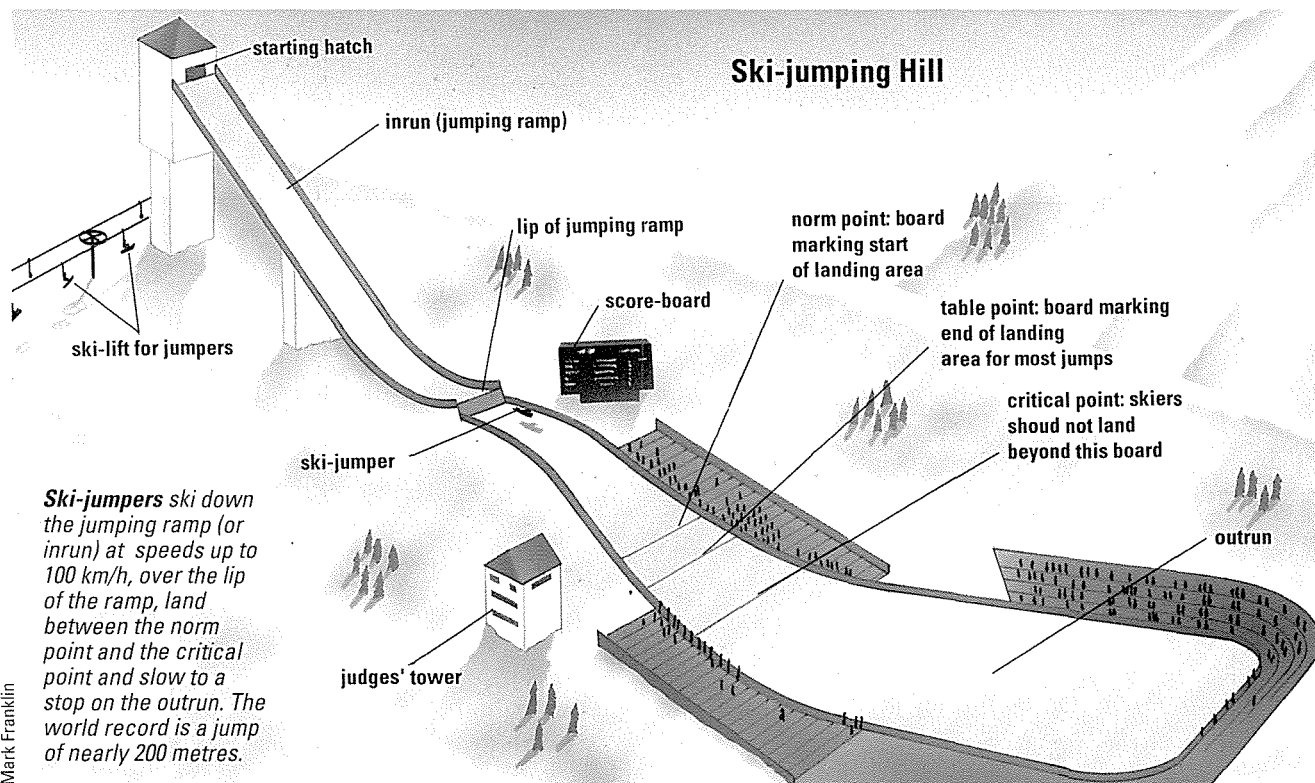
SPEED ON SNOW

THE FASTEST SPEEDS MAN can achieve on land without mechanical help are on snow and ice. Skiing is one obvious example, with some downhill skiers reaching close to 200 km/h. But there are many other types of winter sport that are every bit as thrilling – packed and dangerous, such as ski-jumping, bobsledding and tobogganning.

Competitive skiing can be divided into two main types of event: Alpine and Nordic. Alpine skiing includes slalom and downhill racing, while ski-jumping and cross-country racing are

A downhill racer's gear – from crash helmet to ski poles that fit around the body – reduces wind resistance to a minimum.





Ski-jumpers ski down the jumping ramp (or inrun) at speeds up to 100 km/h, over the lip of the ramp, land between the norm point and the critical point and slow to a stop on the outrun. The world record is a jump of nearly 200 metres.

Mark Franklin

ACROBATICS ON SKIS

Freestyle skiing has become more and more popular in recent years – a reaction to the strictly stylized moves required in conventional skiing competitions. At *aerial* events, skiers perform upright jumps and single, double and even triple front and back somersaults. *Mogul* skiers jump and turn to music as they ski down a special – very steep – slope. *Freestyle ballet* is slightly easier. Competitors 'dance' to music on a gentle slope, using their skis and ski poles to maximum artistic effect.

The skill of slalom skiing is to complete the course in the fastest time, without missing any of the gates, although hitting or knocking out a pole is allowed as long as the skier passes through the gate. Because the turns are so tight, the maximum speed of a skier in a slalom race will only be around 40 km/h. Giant and super-giant slalom runs are much faster, because the courses have larger drops and more widely spaced gates. In all forms of Alpine skiing, times are

reach 140 km/h. Skis used for downhill racing are heavy, long and wide. Smaller skis, more suitable for turning and twisting, are worn in slalom events.

Even faster than downhill racing is a speed trial known as the 'flying kilometre'. The short course slopes at an angle of 45° for most of its length. A skier, timed over the last 100 metres, may reach speeds of over 200 km/h. The problem then is to stop safely, so

Speed skater
Bonnie Blair from the USA. The blade on a speed skate is reinforced with steel tubing to strengthen it.

measured electronically. The timer starts when the skier breaks an infrared beam or mechanical starting gate at the beginning of the course (see NEW TECHNOLOGY pages 183-4).

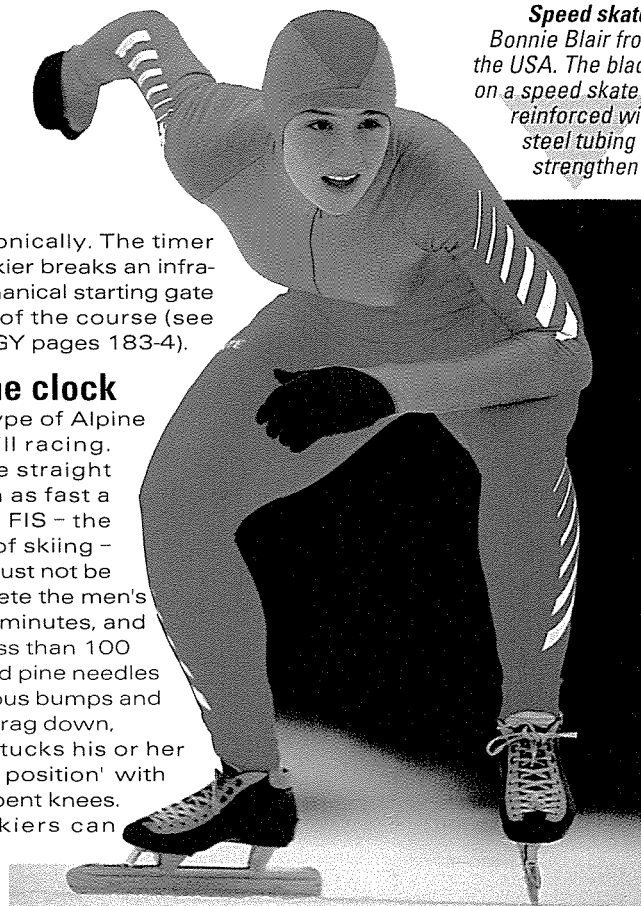
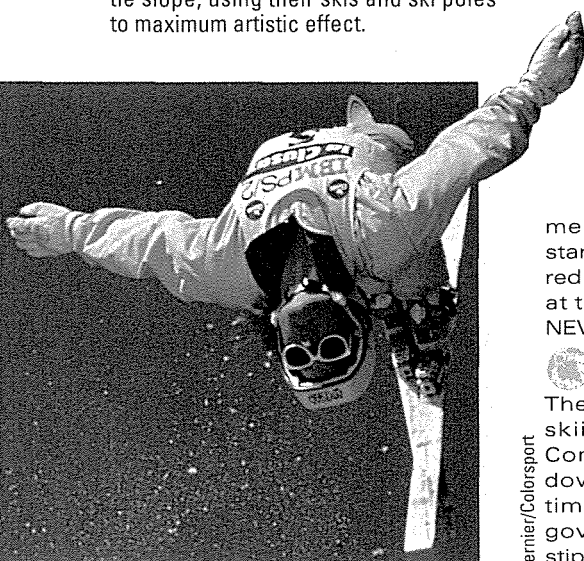
Against the clock

The other main type of Alpine skiing is downhill racing. Competitors race straight down a course in as fast a time as possible. FIS – the governing body of skiing – stipulates that it must not be possible to complete the men's run in less than 2 minutes, and the women's in less than 100 seconds. Scattered pine needles mark any dangerous bumps and dips. To keep air drag down, a downhill racer tucks his or her body into an 'egg position' with elbows touching bent knees. At top speed, skiers can

classed as Nordic events.

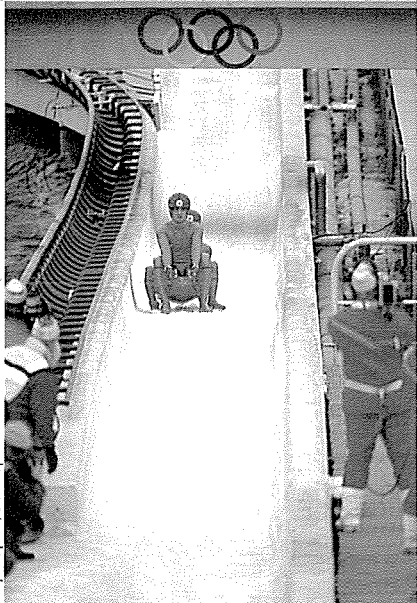
In slalom races, the skier has to follow a downhill course while weaving in and out of 'gates' – usually marked by flags. The gates can be 'open', that is, positioned across the hill, or 'closed', which means the line of the gate follows the line of the fall.

Tavernier/Colorsport



Bob Martin/Allsport





Sipa Sport/Colorsport

the slope flattens out and runs uphill slightly for at least 300 metres. But the skier may still be flung off balance as his skis slow down.

At the other extreme, Nordic cross-country skiing courses can be as long as 50 km (15-50 km for men; and 5-20 km for women). Courses are flatter than in Alpine racing and require stamina rather than speed – skiers have to ski uphill as well as down.

A luge run finishes at the 1988 Calgary Winter Olympics, where the ice-covered, refrigerated track is over 1,000 metres long.

A bobsleigh team, (driver, brakeman and two extra riders) push-starts the bob together. Once under way, bobsleighs reach speeds of 150 km/h.

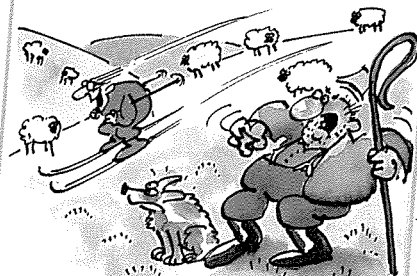


Vandystadt/Allsport

Just amazing!

WELL OFF-PISTE

SNOW IS NOT THE ONLY NATURAL SURFACE FOR SKIING. GRASS SKIING HAS ITS OWN WORLD CHAMPIONSHIP, WITH A RECORD SPEED OF NEARLY 87 KM/H.



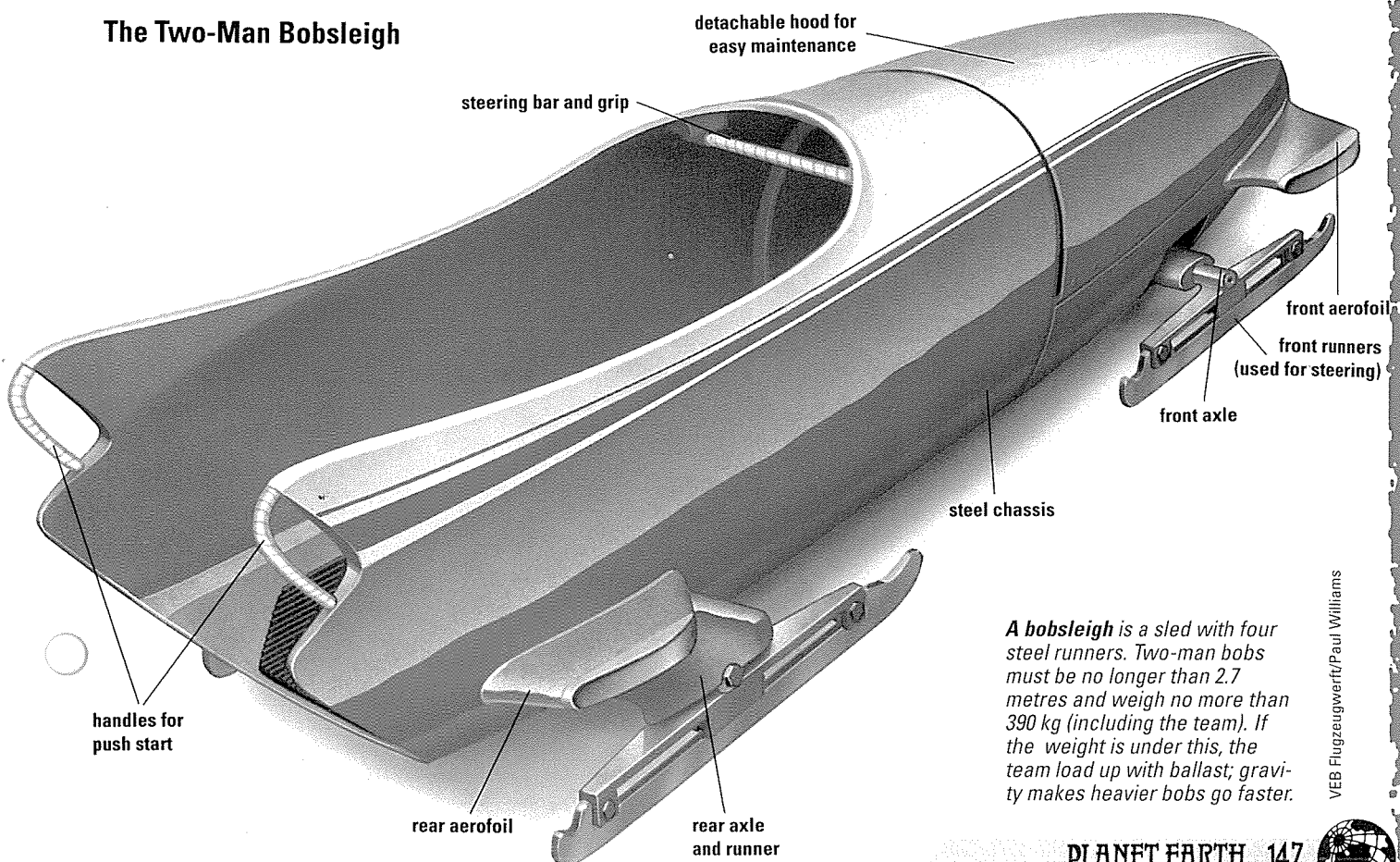
Paul Raymond

Ski-jumping is spectacular and very dangerous. A skier hurtles down the jumping ramp of a specially-constructed jumping hill, from which he takes off into the air at speeds of around 100 km/h. He travels at least 100 metres in the air before landing – the world record for the total jump is nearly 200 metres.

Over the edge

Judges sitting in an observation tower give points for the distance covered before landing and for style. If a skier touches the snow or his skis with his hands (no ski poles are allowed) during takeoff, flight or

The Two-Man Bobsleigh



A bobsleigh is a sled with four steel runners. Two-man bobs must be no longer than 2.7 metres and weigh no more than 390 kg (including the team). If the weight is under this, the team load up with ballast; gravity makes heavier bobs go faster.

VEB Flugzeugwerft/Paul Williams



NEW WAVE SKIING

Bored with racing and jumping, skiers have combined skills from different sports to create new activities. *Snowboarding* is a little like skiing on a skateboard. The snowboarder stands on the 'deck' of the snowboard just like a surfer, except that the feet are secured with fixed bindings. *Parapente* is paragliding on skis. An enthusiast skis over the edge of a precipice and glides down to the valley floor with the help of a parafoil (a cross between a kite and a parachute). The parafoil is then packed into a bag and taken up in the lift for the next time. The toughest of the new disciplines must be *ski extreme*, a cross between mountaineering and skiing. Ski extreme enthusiasts aim to make first descents rather than first ascents, climbing a peak on foot (or using a helicopter), then skiing down the rocky mountainside.

landing, it is considered a fall and he may only score 0-10 points. A skier who does not fall may score between 6 and a maximum 20 points.

High-speed sleds

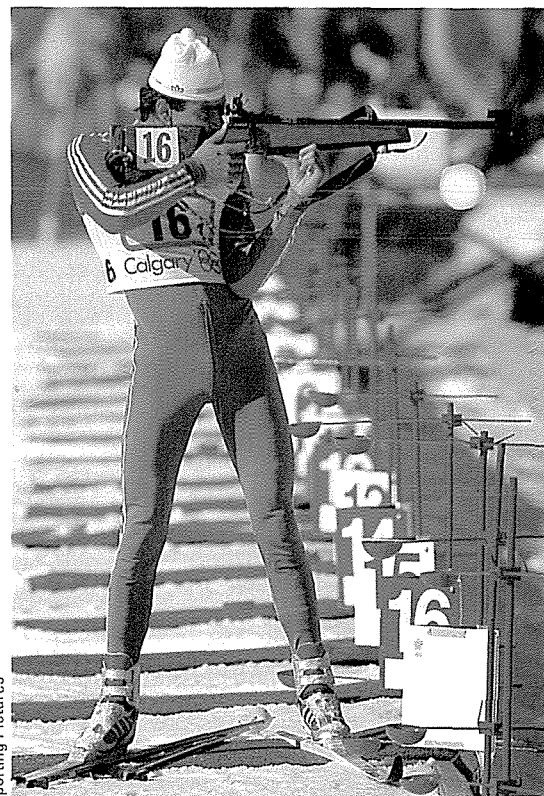
The bobsleigh was invented by a group of Englishmen in Switzerland in 1890, when they added runners to their toboggans (sleds) to make them go faster. Teams of two or four men try to get their bobsleigh down the course in the fastest time. The bob starts about 15 metres before the start line. The team may push the bob as far as they like before jumping in; timing starts as soon as the front of the bob crosses the starting line.

Chris Cole/Split Second

An ice speedway track must be at least 10 cm thick. An ultrasonic pulse is sent through the ice and the time taken for it to return indicates the depth of the ice.



The biathlon combines skiing and cross-country shooting. After each circuit of the 4 km course, the skier fires 5 rounds with a 4.5 kg rifle at targets that are set 50 metres away.

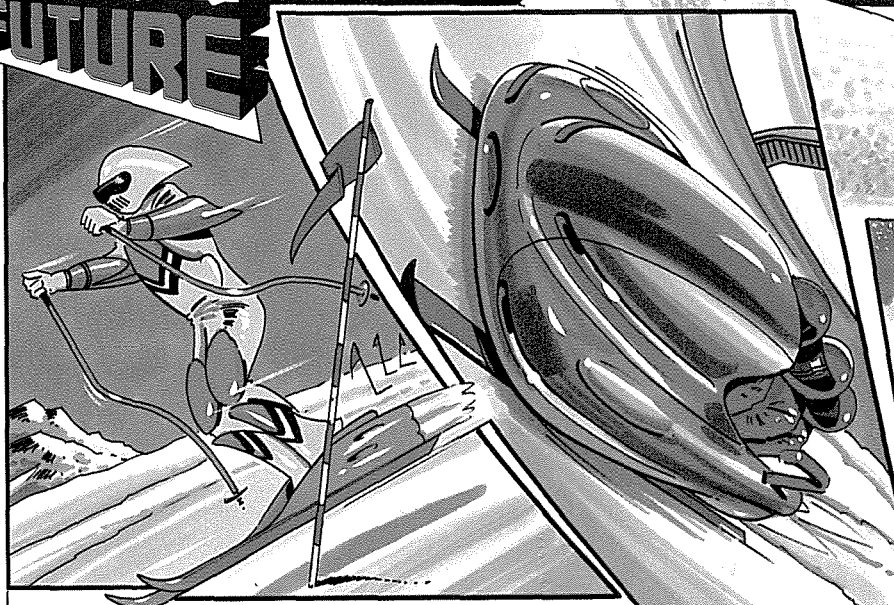


Sporting Pictures

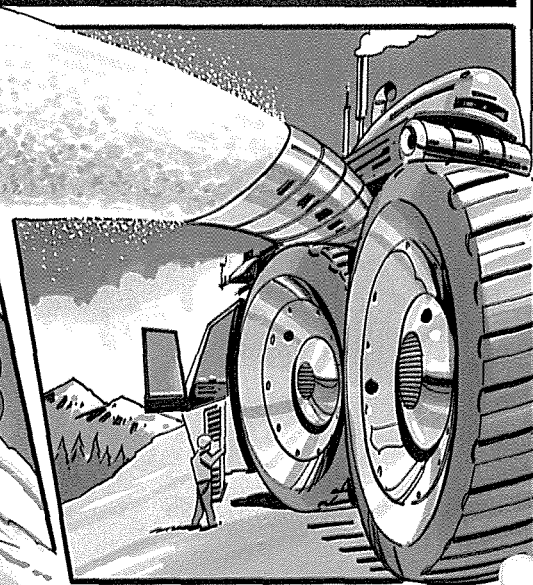
keep critical points of the run frozen during warmer weather spells.

Another of the toboggan's modern descendants is the luge (French for toboggan), on which one or two riders lie on their backs and travel feet-first. Riders can only steer by pulling on reins attached to the runners, squeezing the runners with their legs and by shifting their weight. No other forms of steering are allowed, even though the luge may reach speeds of up to 125 km/h.

INTO THE FUTURE



POWER SKIING



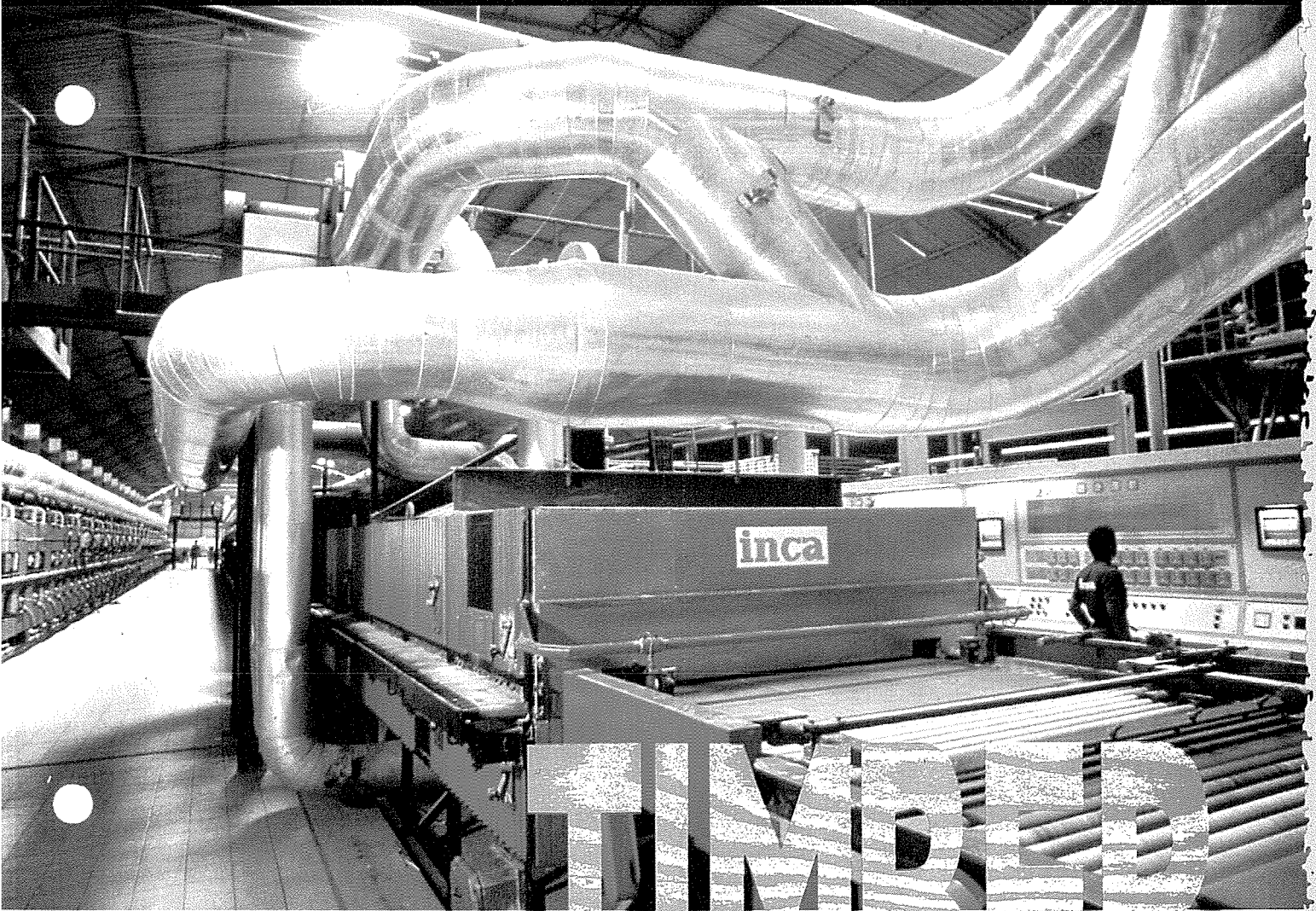
Joe Lawrence

▲ Motorized jet skis are an increasingly popular way of travelling around ski slopes, and may one day feature in downhill or slalom racing.

▲ All forms of racing, from downhill skiing to bobsledding, could benefit from rocket propulsion, leading to even faster and more spectacular events.

▲ At the same time, huge refrigeration units and more sophisticated artificial snow machines will keep skiing conditions perfect all year round.





TIMBER

Man's timber demands have increased greatly in the last century but his wood harvest has not. The technology of modern sawmills has ensured more efficient use of raw materials and processing of all its 'waste'



Floating logs is often the cheapest way of transporting them. In remote areas, with no other river traffic, logs can be carried downstream by fast flowing rivers. Or logs can be tied in bundles and harnessed for towing by tugs over still waters.

WOOD IS TOUGH, DURABLE and plentiful. It can be cut into any shape and has an attractive appearance. Not surprisingly, then, it is the world's most widely used natural material.

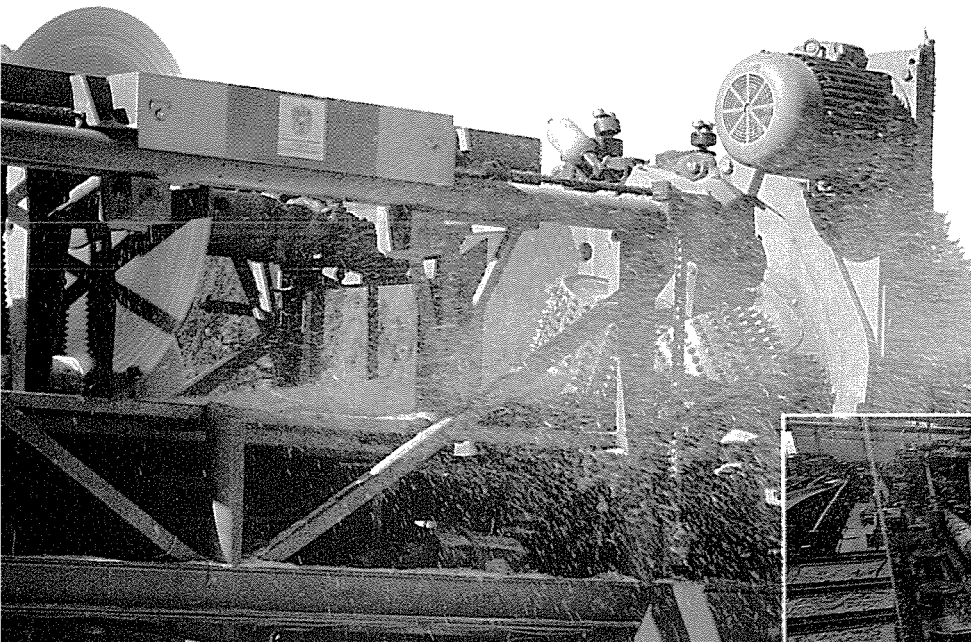
The wood of a tree has two important functions. It conducts water from the roots up to the leaves and it strengthens the trunk, enabling it to remain upright. Wood formation begins in a small green shoot. Inside the shoot are water-conducting cells contained in several bundles, known as vascular bundles. These are arranged in a ring around the inside of the shoot.

Water-conducting cells

The cells, known as xylem cells, are tube-shaped. The cell walls, like the walls of all plant cells, are made of the chemical cellulose, but in xylem cells

ZEFA



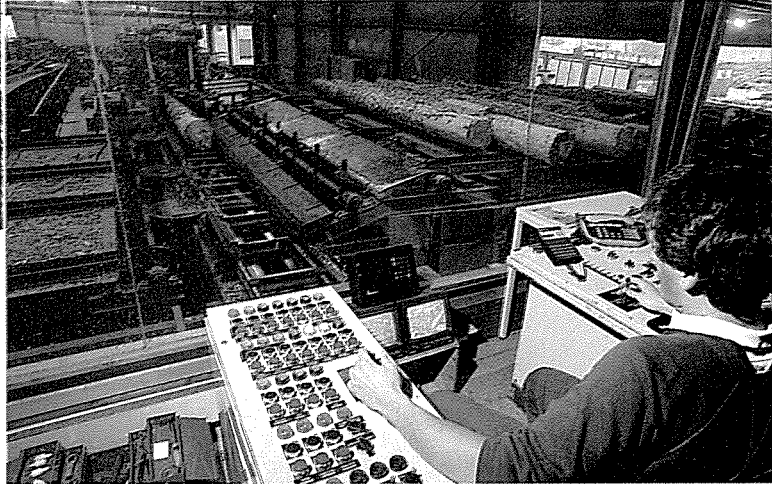


the walls are additionally thickened and strengthened with a substance called lignin. Each vascular bundle also contains food-conducting cells, called phloem cells, which lie on the outside of the bundle and are separated from the xylem cells by a layer of cells known as the cambium.

Growing layer

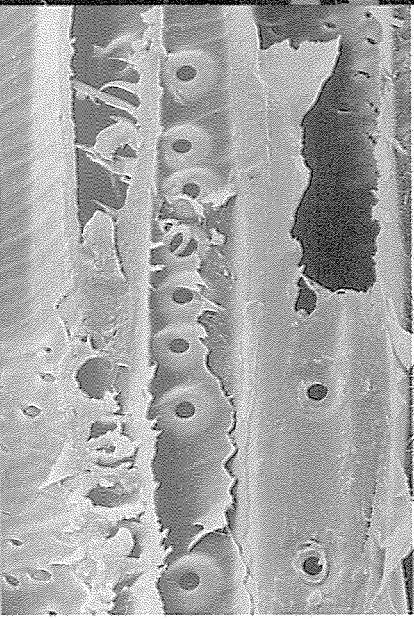
As the shoot grows larger, the cambium of each bundle links up with the cambium in the bundles on either side of it, to form a cylinder. The cambium

ZEFA



Debarking tree trunks is the first function of the sawmill. This process is often computerized (far right). A vertical section through a Scots pine (right, magnification x 100). In softwoods, these tubes, or tracheids, conduct sap (water and nutrients) and give support to the tree. The tiny holes or 'pits' allow sap to pass between cells.

Dr Jeremy Burgess/Science Photo Library



A section of a tree stem shows the growing cambium layer. This produces xylem cells on the inside that form the tree's heartwood and phloem cells on the outside that form the bark.

Ivaldi/Jerrican

cells start to divide, producing new xylem cells on the inside of the cylinder and new phloem cells on the outside.

Heartwood

The tough xylem cells form a layer of wood that becomes thicker and thicker as the years pass. However, only the most recently formed wood is used for water-conduction. The wood at the centre tends to fill up with minerals and forms the heartwood. The layer of phloem does not build up. The thin-walled cells are replaced with new ones each year. In order to protect the vulnerable phloem cells, a thick bark develops on the outside of the tree.

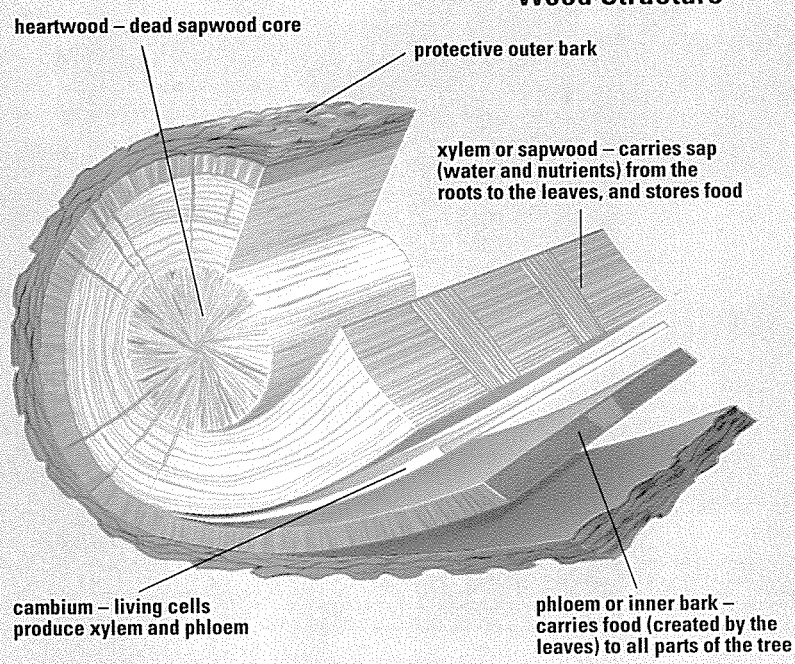
Seasonal growth

Wood formation does not necessarily go on all the time. In temperate climates, trees form new wood only during spring and summer. While cells formed in the spring are large, those formed later get progressively smaller until cell formation ceases completely in late summer. Next spring, wood formation begins again and there is a sudden change from small, late summer cells to large spring cells.

Tree rings

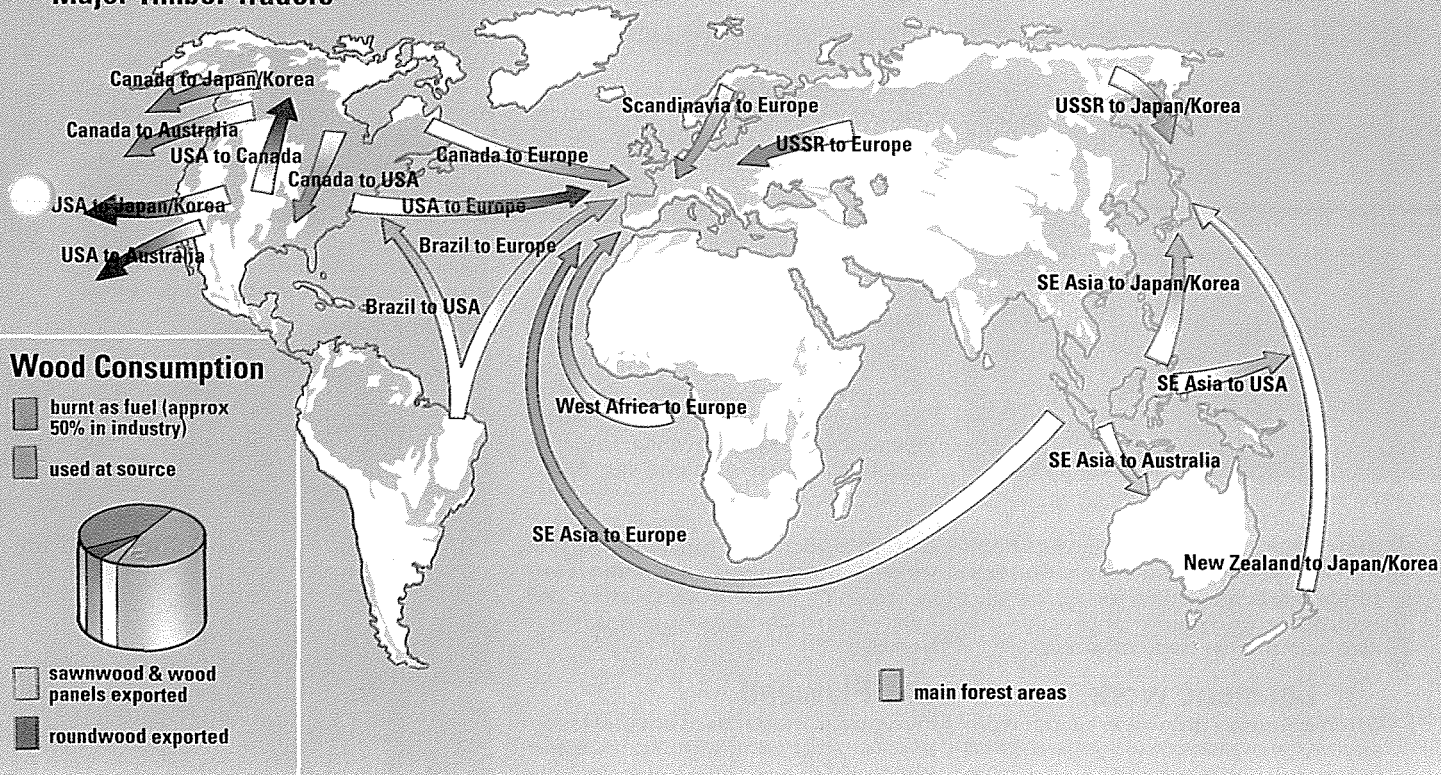
In a tree stump or felled trunk these cells show as light and dark rings (see PLANET EARTH page 68). By counting these annual rings, you can find out the age of a tree when it was felled. In rainy years, trees will produce a lot of sapwood, creating wide rings, and in dry years trees will form

Wood Structure



Joe Lawrence

Major Timber Traders



World trade in timber accounts for a small percentage of the wood Man uses annually – a staggering 3,352 million cubic metres in 1987.

ENGINEERED WOOD

Wood without knots and lumps of resin is known as clear lumber. Builders prefer to use this for surfaces that have to withstand all kinds of weather. But clear lumber is becoming scarce. World wood supplies have been used at a faster rate than they can be replaced for the last thousand years. Softwoods are not in danger – coniferous trees grow fairly rapidly – but hardwoods are beginning to disappear. Scientists in the USA have devised an alternative particle board: wood chips are first reduced to a fibrous pulp that is then mixed with wax and plastic (phenolic resin); the mixture is heated and pressed into a board that looks similar to natural wood but is waterproof and does not decay, warp or crack.

smaller, compacted, dark rings. By studying these rings – a science known as dendrochronology – scientists have built up a picture of world climates stretching far back in history.

Wood fibre

Woods are classified in two main groups – softwoods and hardwoods. Softwoods come from coniferous trees, such as pine, spruce and fir. Their xylem cells are known as tracheids and those produced in the summer have thicker walls than the spring cells. These late summer cells provide most support for the tree.

Hardwoods come from broadleaved trees, such as oak,

beech, teak and poplar. Their support is provided by many small fibres. Their water-conducting cells are much larger and, if the end of a cut stem or branch is examined closely, they can be seen as a number of tiny

However, drying timber in a kiln is quicker and more reliable.

A great deal of softwood is pulped for making into paper and board. All kinds of wood are processed for buildings, furniture, boats, musical

Simon Critchley



Many wood-exporting areas of the world – such as Sri Lanka – operate without the benefit of power tools and computers. Cutting wood along its length (below) reveals its grain. The grain of a wood depends on the arrangement of its fibres and sap-conducting cells.

holes, which are called pores.

Wood is processed at a sawmill. Each log is debarked and then either pulped for paper or cut up into squared off timbers and planks by mechanical saws. The boards are then graded for quality and stacked.

Seasoning

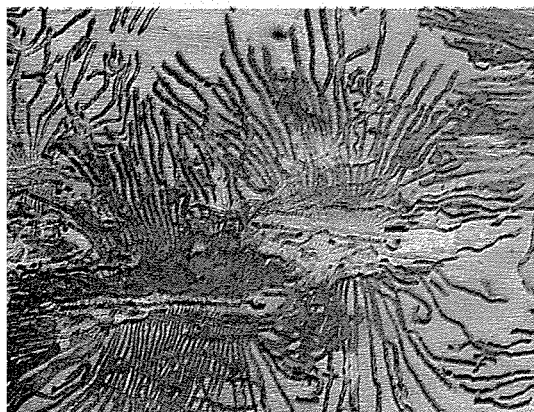
Before this wood can be used, it has to be dried, or seasoned, in order to remove the sap. Unseasoned wood is prone to shrinking and warping. Seasoning can simply be done by allowing the wood to dry out naturally over a period of a year or so.



Coty/Jerican



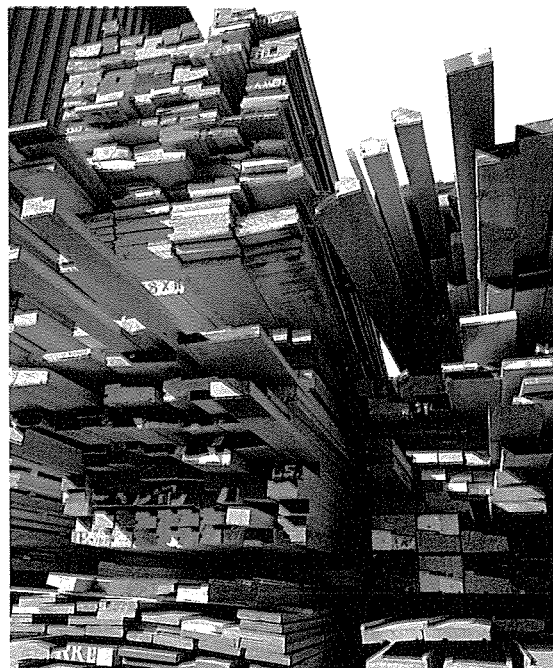
DUTCH ELM DISEASE – SLOW TREE-KILLER



Dutch elm disease is a fungus that causes a gradual withering of trees. In the 1970s it killed approximately 20 million of the 23 million elm trees in southern England alone. Fungal spores are transmitted from tree to tree by bark beetles that burrow under the tree bark leaving distinctive channels (left). There is no known cure for this disease but its spread can be checked in several ways. Controls can be exercised on imports and exports of wood and its products. Diseased consignments can be destroyed, fumigated or kiln-dried to kill the carrying beetles. Living trees with Dutch elm disease should be destroyed.

clear land for farming, and are being damaged by atmospheric pollution.

Acid rain is caused by the build-up of chemicals in the atmosphere from the burning of fossil fuels such as coal and oil. It was first identified over 100 years ago but its effects on forests only became apparent in the 1970s. The first symptom of damage is reduced growth followed by abnormal loss of foliage, distorted branching,



Planks and mouldings are colour-coded for identification at a timber merchants after being cut, graded for quality and seasoned to remove sap.

mineral imbalance and increased vulnerability to frost, drought and pests. Only worldwide attempts to reduce drastically emissions of sulphur and nitrogen oxide can restore our atmosphere to its pre-industrialized state and safeguard the world's trees.

GSF Picture Library

instruments, toys, kitchen utensils and ornaments. Railway sleepers, fence posts and poles for supporting telephone and electricity cables are also commonly made of wood.



Cosmetic work

Often a veneer (thin layer) is cut from an attractive piece of wood and glued to a base wood, to give an attractive

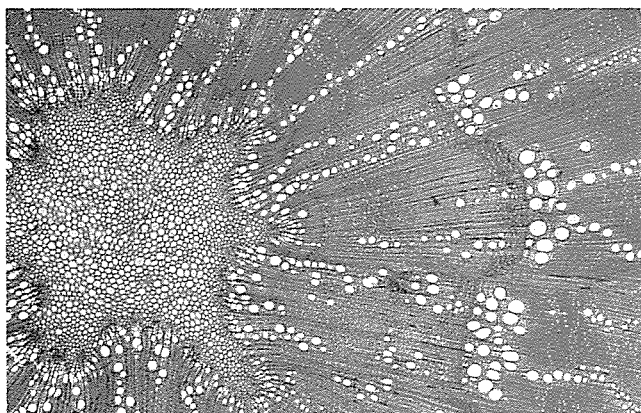
strong boards a couple of metres wide. Nothing need be wasted. Even wood chips and shavings can be processed into chipboard and particle board.



Plywood

Plywood is made up of several layers of rotary-cut veneer glued together. Knots are cut out and holes and slits

Sinclair Stammers/Science Photo Library



The dense heartwood of an oak tree can be seen in this light micrograph. Rings of large and small cells are also visible. Each ring represents one year's growth.

An artificial wood pattern is applied to hardboard using a type of printing press. The sheet of hardboard is attached to a drum and paint is transferred by pressure using rollers. Hardboard is made – like paper – from wood fibres.



Marcelo Brodsky/Science Photo Library

finish to a piece of furniture. Sometimes a veneer is set into a shallow recess cut into the surface of a piece of furniture – a technique known as inlay. In another technique, known as marquetry, two or more veneers are used to create a pattern or picture.

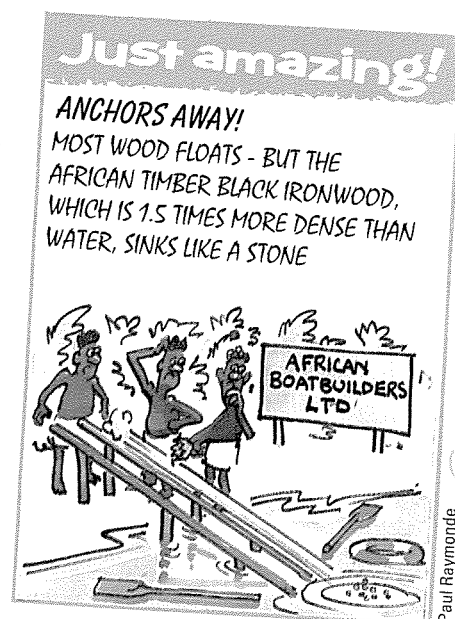
Natural wood has limitations. The largest planks obtained from trees are seldom more than 25 cm wide, and wood is often flawed, with knots, cracks and lumps of resin. However, processing timber can produce

are filled with wood or synthetic filler. The layers are arranged so that the grain directions of alternate sheets are at right angles to strengthen the finished board.



Deforestation

World demand for wood is growing. But supplies are not solely affected by the rate at which we cut down trees for timber. That rate can be controlled to some extent by replanting. Trees are also cut down and burnt to



Paul Raymond





War rages in the streets of Beirut with Christian and Muslim militia battling from house to house. Armoured vehicles are vulnerable in narrow streets, while unsupported infantrymen (left) are more at risk in the wider boulevards.

- 'HOUSE CLEARING'
- SNIPERS
- STRONGPOINTS

SIPA/Rex Features Ltd

URBAN COMBAT

Gamma/Frank Spooner Pictures

ALL MODERN ARMIES ARE trained to fight in urban areas. They learn both to attack and defend cities. The British Army has even constructed a special village in its Salisbury Plain training area where it can practise these techniques.

When attacking an enemy who is defending a city, it is sometimes possible to use the streets by avoiding open areas exposed to enemy fire. But often it is necessary to move down the gardens and backyards that run parallel to the streets, across the roofs of buildings, underground through the sewers or drains, or through the interiors of houses by 'mouseholing' through the dividing walls. Progress is slow, sometimes painfully slow, as the troops fight their way from house to house.

Street clearing and 'house clearing' require special skills. Fighting is at very close quarters with the enemy only a street or a house away. Sometimes he is only a room away on the other side of a wall. The infantryman has to be prepared for hand to hand combat. His reactions must be instantaneous - there are no second chances.

Enemy fire

One problem of fighting in the cities is the difficulty of locating the source of enemy fire. The crack of a high velocity rifle echoes and re-echoes off surrounding buildings so that it is virtually impossible to be sure where the round is coming from.

Urban warfare is sometimes further confused by the smoke and dust that hangs in the streets. Fields of fire and of observation are much more restricted than the infantryman is used

to, although there is probably more and better cover than in a rural environment. Invariably, it is the attacker who must show himself in order to make progress.

Snipers defending an urban stronghold can cause difficulties. They are usually so well hidden that it is difficult to get an aimed shot at them. The usual response is to fire an anti-tank weapon at the window or part of the house from which it appears the fire is coming - overkill perhaps, but this is very effective nonetheless.

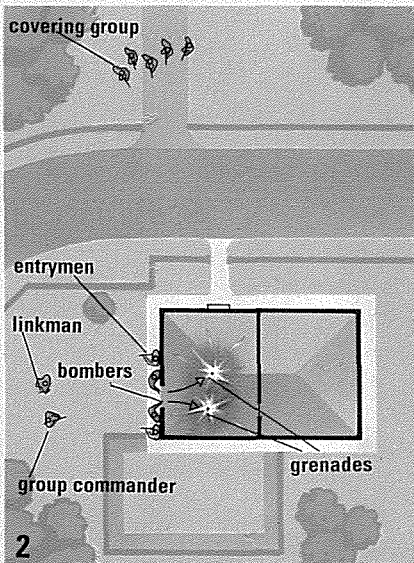
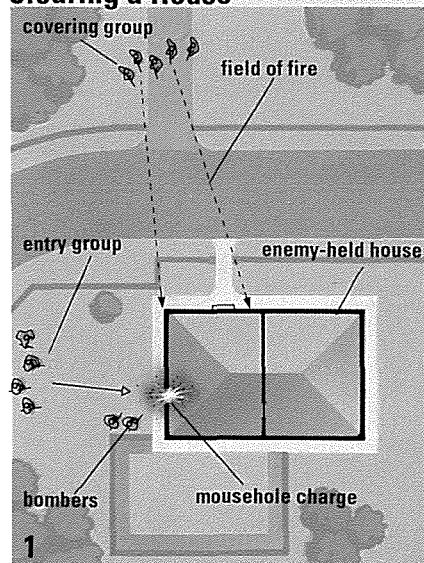
Use of tanks

Tanks can provide very effective close support, but in a narrow street, they are very vulnerable. An anti-tank weapon can be fired into the side or rear of the tank at very close quarters.

There are, of course, other difficul-



Clearing a House



Under covering fire, the bombers place a mousehole charge (1) to flush out enemy forces. Grenades clear the first room (2). Entrymen shoot at concealed enemy 'mouseholes' (3) before moving on. The commander controls the timing, while the linkman relays orders to the covering group (4).

with strong walls made of brick and stone are the best for defence.

Soldiers use various ways to strengthen a chosen strongpoint building. Sandbags can be piled against the walls. Cupboards or chests of drawers or even mattresses can be filled with earth and staircases and doorways barricaded.

Shock of explosions

Movement around the building should be via holes in walls and ceiling by means of ladders, ropes or piled up furniture. Ceilings are prepared for the shock of explosions by shoring them up with strong timbers resting on a solid base and wedged against solid parts of the building.

The troops' next task is to site the weapons. Automatic weapons should be sited near ground level. A machine gun can cover a long zone if the rounds are travelling parallel to the ground. That way they can cut down both enemy troops nearby and those further away in a single sweep of the gun.

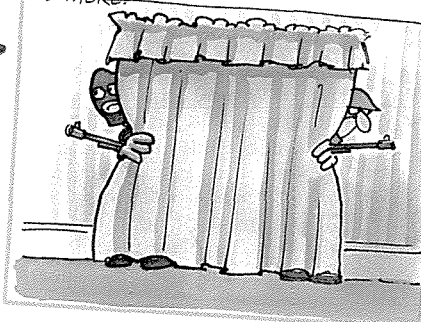
Siting snipers

Snipers, however, are better sited up where they can see further. A rifleman firing through a window should be as far back as possible so that he cannot be seen from the outside. Even better, he should construct a loophole underneath a window sill or through the tiles in a roof. Hand-held anti-tank weapons should be sited in upper storeys so they fire down on to the tops of armoured vehicles, which are less well protected.

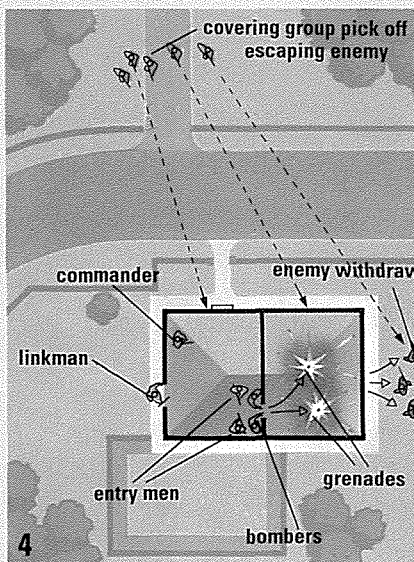
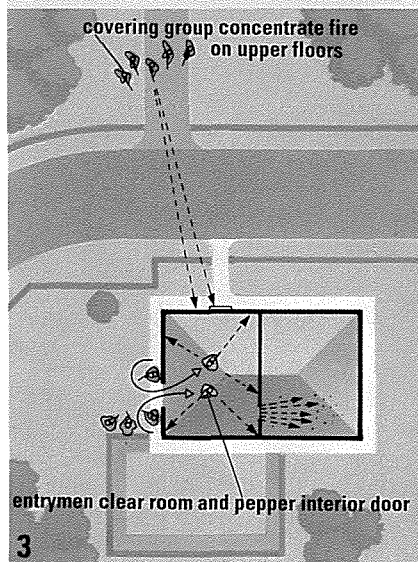
Just amazing!

NEIGHBOURS

TECHNIQUES OF URBAN COMBAT HAVE BECOME SO SOPHISTICATED THAT IT IS NOT UNCOMMON FOR ATTACKERS AND DEFENDERS TO OCCUPY THE SAME HOUSE WITHOUT REALIZING THE OTHER IS THERE.



Paul Raymonde



ties of using tanks in places such as Northern Ireland where there are many ordinary citizens in the streets going about their everyday business. In this situation, a tank's massive firepower is far too indiscriminate to be used.

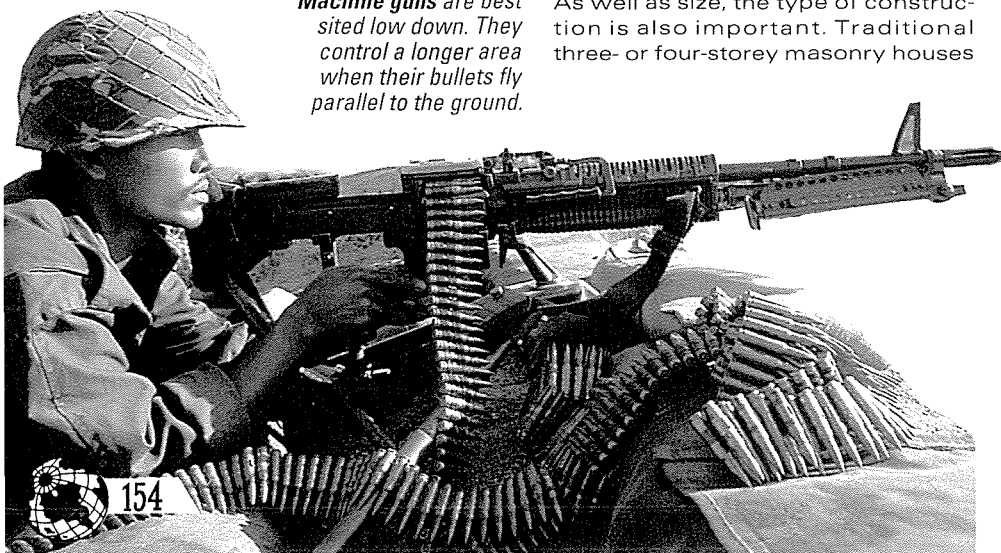
When defending a city, the business of fighting from building to building needs careful thought and a great deal of preparation. It is important that the right building is selected

for a strongpoint. If it is too small, a single hit from an artillery shell or a direct hit from a tank could well kill everyone in the building. On the other hand, a building that is too large may mean the defenders are spread so thinly that they are unable to cover all the approaches or provide an adequate concentration of fire to prevent the enemy storming – and overrunning – the building.

Defending a house

As well as size, the type of construction is also important. Traditional three- or four-storey masonry houses

Machine guns are best sited low down. They control a longer area when their bullets fly parallel to the ground.



■ CAMOUFLAGE

■ CONCEALMENT

■ CONFUSION

DECEPTION TECHNIQUES

AS MODERN SURVEILLANCE equipment becomes increasingly sophisticated, methods of concealment and deception on the battlefield are improving to cope.

The NATO definition of deception is: "those measures designed to mislead the enemy by manipulation, distortion or falsification of evidence, designed to induce him to reach a conclusion in a manner prejudicial to his interests." Other words to tick the enemy: "the use of camouflage or concealment of dummies, decoys, feints, lures and traps, and all forms of deception."

Camouflage is the simplest form of deception. It is designed to make a completely hidden person or object, from the enemy or, in this instance,

Facial camouflage matches skin colour to that of the surrounding and disguises the familiar shapes of the head, eyes, nose and mouth.

possibly, soldiers, or the search for enemy assets to their advantage.

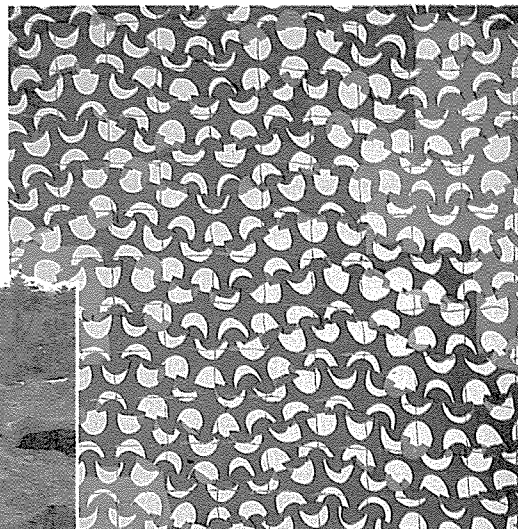
Camouflage can be applied to a person's uniform, the side of a tank, the hull of a ship, or even the camouflage of a tank and can be painted, sprayed or even made of paper.

Camouflage netting is applied to vehicles and equipment to protect it from the enemy's view.

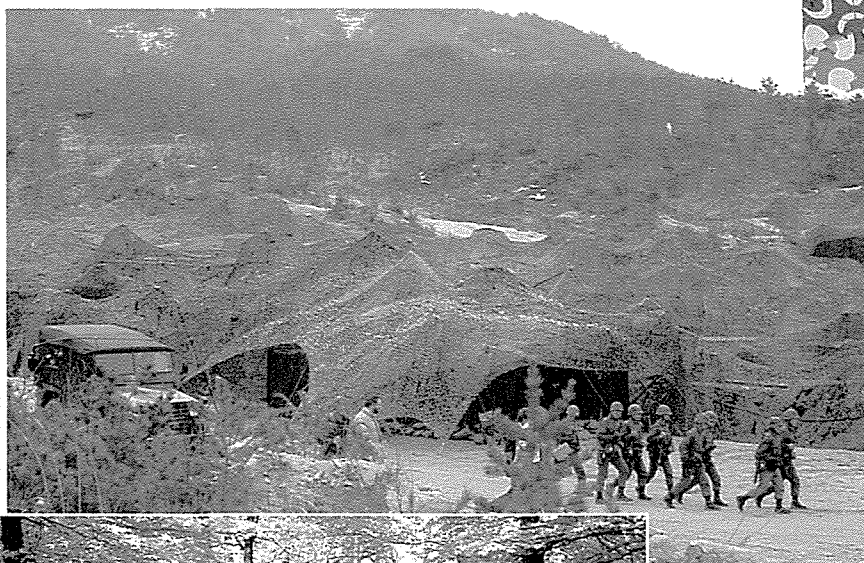
Camouflage nets are used in ships' harbours, can also be camouflaged effectively. A ship is moved alongside a quay, preferably into a barge. A lightweight tubular framework is lifted, lowered and erected. This framework's straddles the space between the ship and the quay and is clad with camouflage netting so that from the air, the ship looks like an extension of the quay.

Aeroplanes can be camouflaged, not only to merge with the ground when looked at from above, but also to merge with the sky. The camouflage consists of three shades of grey. Dummies and decoys are another means of deception. Dummy equip-

Camouflage nets are made with computer-generated colour patterns to match different terrains – thus guarding against visual detection. Thermal blankets can be used with these nets to trick thermal cameras.



Diab-Barracuda



TRH Pictures

tions can make it more difficult for enemy pilots to locate and eliminate the real ones.

Inflatable bridges and missile systems are made by a Swedish company called Diab-Barracuda. Their Bailey bridge can be erected by eight men in just one and a half hours. A 30-metre section weighs only 205 kg. Seen from the ground or air, even at close range, the bridge looks remarkably like the real thing.

Radar nets positioned over reflecting objects scatter most radar waves. A tank (left) seen through an infra-red camera is disguised by a net designed to reflect infra-red light in the same way as its surroundings.



Smokescreen

Smoke is another means of deceiving the enemy. Troops can advance or withdraw under its cover and it can be used to confuse and disorientate the enemy. It can be used on a grand scale over many miles or smoke can be produced in localized

ment is designed to make the enemy think you are somewhere you are not. Dummy equipment is simulated.

A decoy may or may not be the real thing. Its purpose is to attract the enemy's attention and, more particularly, his fire. It is often a dummy tank or an abandoned real tank.

False tracks

A complete dummy position near an actual position can be made more realistic by, for instance, having a mess tin glint in the sun, by making vehicle tracks into and out of the position and by stationing one or two men there to provide signs of movement and occupation. If, at the same time, the actual position is concealed particularly well, the enemy may be encouraged to waste his fire on the wrong position and, when he attacks it, he may leave himself open to attack in the flank.

Bailey bridge decoy

Combat engineers often employ deception techniques. For instance, during an advance or withdrawal overland, an army depends to a very large extent on the bridges it has erected over rivers for its logistic support – assuming that permanent bridges have been destroyed. Also a large number of dummy missile posi-

Concealment is as important as camouflage. These men are careful not to 'sky line' – reveal their silhouettes by walking across the top of a hill. A British RAF Harrier Jet (above) in snow camouflage colours.



US Navy/TRH Pictures



areas with the 51 mm mortar or by using smoke grenades. If used correctly, smoke can deceive the enemy as to which way an attack is coming.

Dummy heat sources

It is also possible to deceive the enemy by creating false heat sources. Concentrations of men and equipment carefully hidden in woods can easily be detected by modern surveillance equipment – such as thermal imagers and Infra-red Linescan photography.

While it is difficult to counter these devices by reducing the heat signature of real vehicles, it is possible to



Smoke is used to disorientate the enemy, shield troop movements and for signalling. Smoke generators aboard amphibious craft (left) emit a dense white smokescreen to obscure their movements.

a missile site or a supply depot. Even if the enemy knows where these are, they can be concealed or disguised.

Foam

Parallel aprons and dummy aircraft can be created on airfields to mislead pilots of attacking aircraft. Coloured foam (which lasts for several days) can be used to remove key indicators such as road junctions, perimeter tracks, and runways to confuse pilots.

Air attack

It is necessary for the pilot of a modern jet to spot his target from a distance of 4 km if his attack is to be successful. At 4-km range, flying less than 50 metres above the ground and closing at 920 km/h the pilot will catch sight of perhaps the perimeter fence and track, roads and other paved surfaces, the pattern of buildings, equipment in the open and prominent landmarks near the base. Much can be done to 'tone-down' all these tell-tale signs.

The perimeter can be toned down

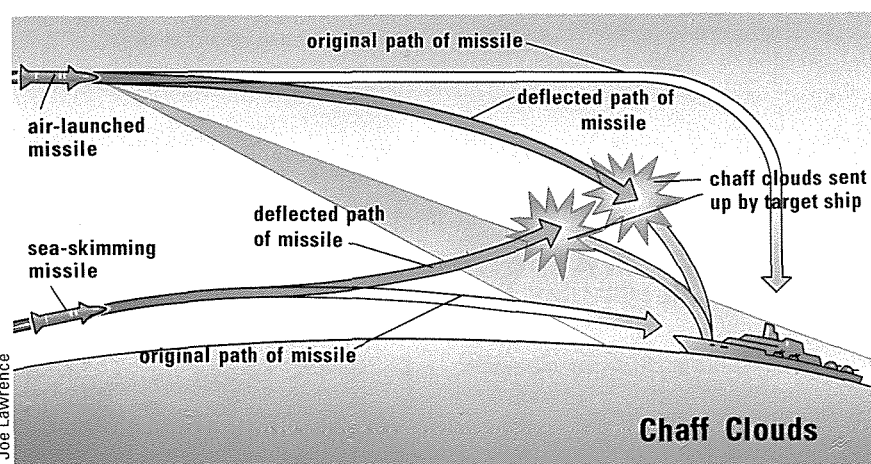
confuse them by putting dummy heat sources, such as paraffin heaters, in woods where there are no troops.

Misinformation

Radars constantly survey the battlefield. By using anti-radar camouflage nets to hide real vehicles and by creating false echoes else-

time for a successful attack to be mounted elsewhere. Similarly, false information may be provided over real radio nets in the hope that the enemy will be listening in.

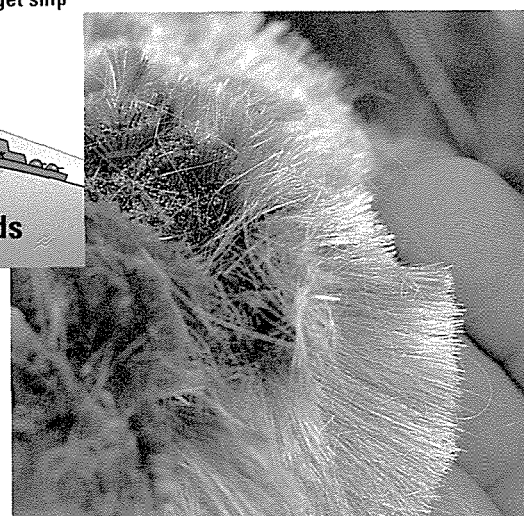
Behind the front line there are a number of sizeable and static installations on which troops may depend for support – whether it be an airfield,



where, the enemy can very easily become confused.

Radio traffic can also be used to simulate a non-existent formation of troops. Radio operators talking to each other about fictitious plans for an attack can fool the enemy. Even if a hoax is uncovered after a few days or a few hours, it may provide vital

Naval chaff rockets, shot from a ship deck, carry chaff 1,000 metres into the air to lure anti-ship missiles. In the case of a sea-skimming missile, chaff may be launched while a ship is still below the missile's radar horizon. Chaff (right) – tiny aluminium-coated glass fibres.



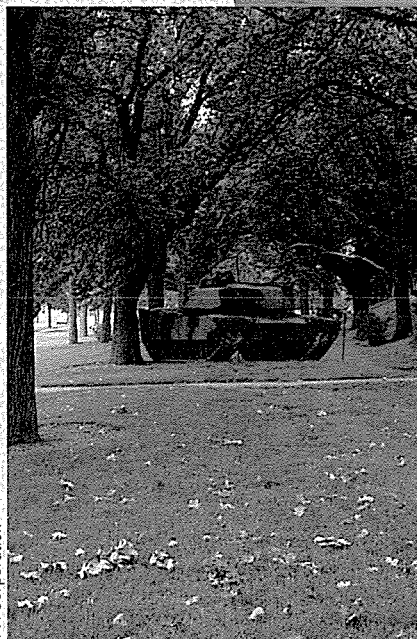
DUMMY AND DECOY TECHNOLOGY



TVI Corporation

The principal problem facing designers of modern decoys is to make them effective enough to fool an enemy's sophisticated sensors, without becoming so complex that they are not cost-effective.

The life-size M1 Tank decoy (top left), developed for the US Army, can be erected in five minutes by two men. Disassembled, it weighs only 23 gm and can be carried by a soldier in a duffle bag. This decoy comprises a four-colour printed canvas skin stretched over a collapsible aluminium frame. The 'tank' is designed to appear three-dimensional when viewed from a distance. Seen through binoculars the effect is even more convincing. Different configurations are available so that 'tanks' appear to the viewer front-on, from an angle, and semi-hidden in a ditch (right – decoy viewed from 100 metres). A heating element and a 1 kW gas generator to fool thermal sensors complete the system.



TVI Corporation

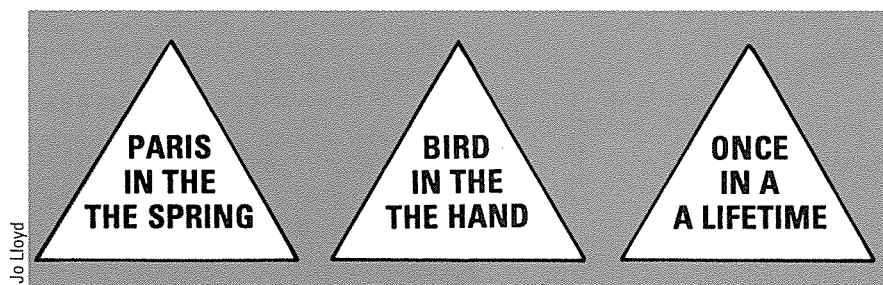
The F-16 Fighting Falcon decoy (below) can be assembled in one hour by four men. It weighs just 730 kg and measures 14.76 metres in length, 9.2 metres in width and 5 metres in height. Plane decoys can be complimented with radar reflection and thermal signatures to make them more effective.

Close up, the F-16 decoy would fool no one. But it is designed to be seen on the runway, by a pilot in the air travelling at high speed. The decoy is sufficiently realistic at a range of 300



metres to distract a tactical attack pilot (a pilot looking for single targets). Travelling at a speed of 835 km/h and at a height of 50 metres, concentrating upon multiple cockpit and weapons systems tasks, a pilot is worried about surface to air missiles and other anti-aircraft fire and has little time to analyse targets. At 250 metres he will have committed himself to expending some of his warload harmlessly on the decoy. As he makes his attack exit, he may just realize that he has risked his life and an expensive aeroplane to attack a fabric model. But by then it may well be too late to make a second approach on a real target.

Diab-Barracuda



Jo Lloyd

by having the same type of ground either side of it; for instance if there is a ploughed field outside the perimeter then the ground inside will also be ploughed.



Anonymity

Trees can be planted to break the outline of buildings and to hide access roads. If roads cannot be hidden they might be made to appear part of the civil system. False roofs can be put on a large flat-roofed building to make it

The British Army use exercises to show that expectations affect what we perceive. In each of these phrases the article – 'the' or 'a' – is printed twice.

look like a row of houses.

Although deception to some extent involves pure cunning it is also a science, and technology plays a vital role. As the threat of war recedes, deception technology may well provide some cost-effective alternatives.



Paul Raymond





WATERFALLS



SHOOTING STARS



PLANET EARTH

GREATEST SHOWS ON EARTH

ZEFA

Mount Tolbachik, on Kamchatka Peninsula in the far north-east of the former USSR, erupted in July 1975. Lava flowed from the volcano at a rate of 165 metres per second.

THOUSANDS FLOCK TO SEE wonders of nature such as Niagara Falls in North America. Other spectacles – eclipses of the Moon and Sun, for instance – can only be seen from time to time and some are unforgettable, once-in-a-lifetime experiences.

Many of the most awe-inspiring natural displays occur in the sky. In the Arctic and Antarctic regions, the sky is often covered with patterns of shifting, glowing, coloured lights. The 'polar lights' are known as aurora borealis in the northern hemisphere and aurora australis in the southern hemisphere. They are caused when electrically charged particles from the Sun, trapped in the Earth's magnetic field, collide with atoms in the atmosphere above the North and South Poles.

Eclipses of the Sun

Unlike aurorae, which are hard to predict, the timing of eclipses of the Moon and the Sun can be calculated years in advance, from their predicted orbits. Total solar eclipses, in which the Moon passes exactly in front of the Sun, are the rarest and most fascinating kind. The track of such an eclipse – the area over which the Moon casts its full shadow, or

umbra – may be only a few hundred kilometres wide and the eclipse never lasts for more than eight minutes. Even so, enthusiasts travel to remote locations such as Antarctica for a glimpse of the event.

This is the only time that the Sun's faintly glowing outer atmosphere – its *corona* – can be clearly seen without the use of any special equipment. The amount of light reaching us from the Sun is reduced to 1/800th of its normal level. The temperature drops as it would at night, stars can be seen in the sky and the light is similar to that on the night of a full moon.

Eclipses of the Sun

Another astronomical show is put on by meteor showers. When the Earth, on its yearly journey around the Sun, cuts across the orbit of a comet, swarms of dust particles that have escaped from the comet hurtle into the Earth's atmosphere and burn up in a series of brilliant flashes. The brightest of these showers of 'shooting stars' are called the Perseids and fall each August, being brightest on the night of the 12th.

Occasionally, large meteors, weighing several kilograms or more, do not burn up completely. These glowing, white-hot fire-balls speed through the atmosphere at up



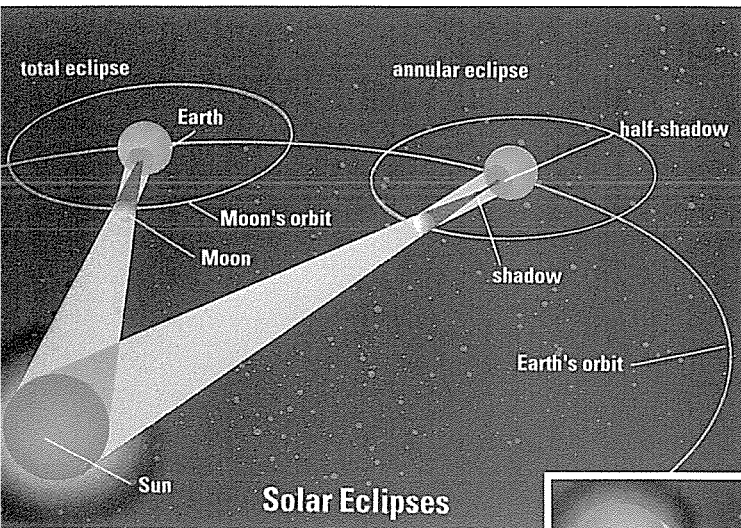
Ronald Royer/Science Photo Library

Millions saw Halley's Comet (here some 60 million km above California) in early 1986, when its orbit took it close to Earth for the first time since 1910.

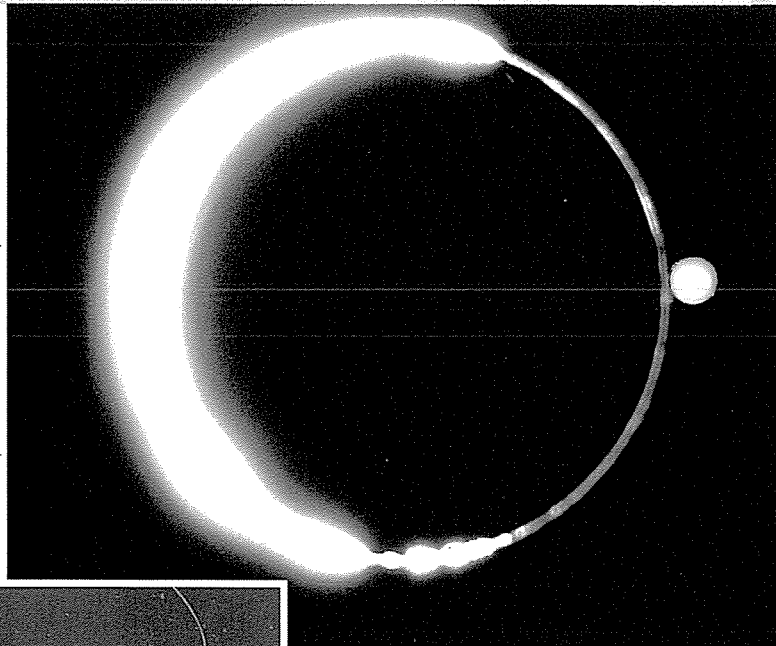
to 20,000 km/h. Many shatter on impact, but some remain intact and blast a hole in the ground.

One such incident happened in Arizona, USA, where Meteor Crater, a depression 1.2 km across and 180





Dr Fred Espenak/Science Photo Library

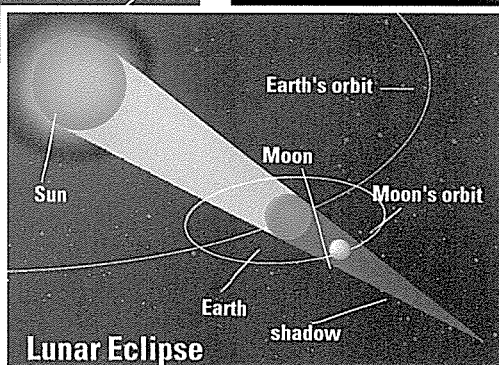


WONDERS OF SPACE

Earth's greatest natural wonders are dwarfed by those on other planets in our Solar System. On Mars, a volcano called Olympus Mons is some 26 km high – almost three times the height of Mount Everest. Another Martian feature, Valleris Marineris, is a canyon eleven times the length and four times the depth of the Grand Canyon in North America. Weather systems too are on a gigantic scale. The Great Red Spot on Jupiter is a swirling storm with a diameter twice that of the planet Earth's.

metres deep, was blasted out of the ground by a meteorite some 25 metres in diameter and 63,500 tonnes in weight that fell to Earth at some point between 2,000 and 50,000 years ago. It is estimated that once every 50 million years or so there occurs a collision between the Earth and an asteroid (a minor planet), which might be comparable in size to a mountain.

Waterfalls are one of the natural world's most breathtaking sights. Angel Falls in Venezuela is the tallest waterfall in the world. It plunges 979



Lunar Eclipse

Solar eclipses occur when the Moon passes between the Sun and the Earth, blocking the Sun's rays – partially, as in the case of this annular (ringlike) eclipse in 1984 in North Carolina, USA, or totally. In a lunar eclipse (left), the Earth passes between the Sun and the Moon, casting a shadow over the Moon and effectively obscuring it.

Mark Franklin

The Iguazu Falls on the border between Brazil and Argentina. Over 270 cascades, some dropping as much as 82 metres, plunge off the Parana plateau into the gorge below.

metres from the Auyan Tepui plateau ('Devils Mountain'). In terms of water volume, the Victoria Falls in Zaire ranks first, with a flow rate of 17,000 cubic metres per second.

Gigantic waves

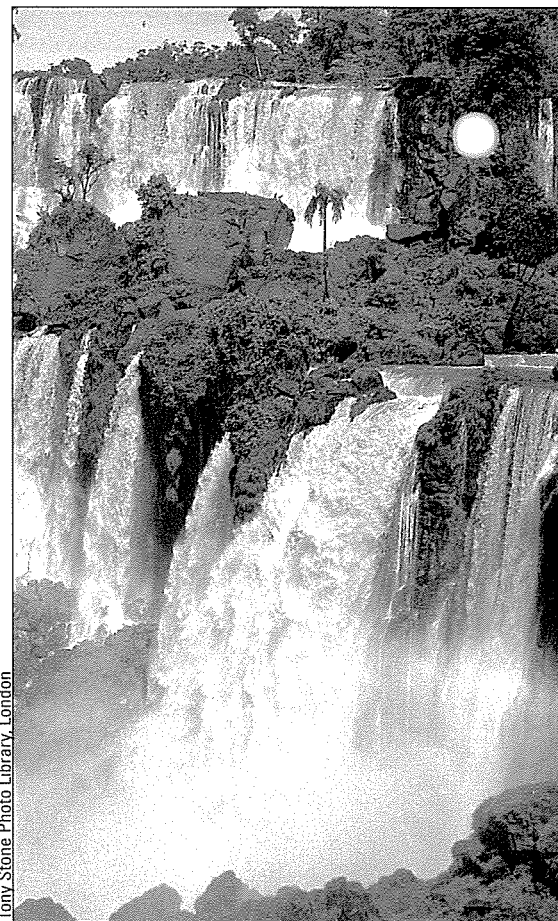
Another amazing water spectacle is a river bore – a single, fast-moving wave that surges up river from the sea at high tide. About 60 are known. The largest of these tidal waves occurs on the Hang-chou-fe river in eastern China. At spring tides, the wave reaches a height of 7.5 metres and a speed of 27 km/h. Its approach can be heard 22 km upstream.

Among the most popular tourist attractions in the world is a geyser – Old Faithful in Yellowstone National Park, USA. Water heated underground to near-boiling point shoots as high as 40 metres into the air.

Deadly eruption

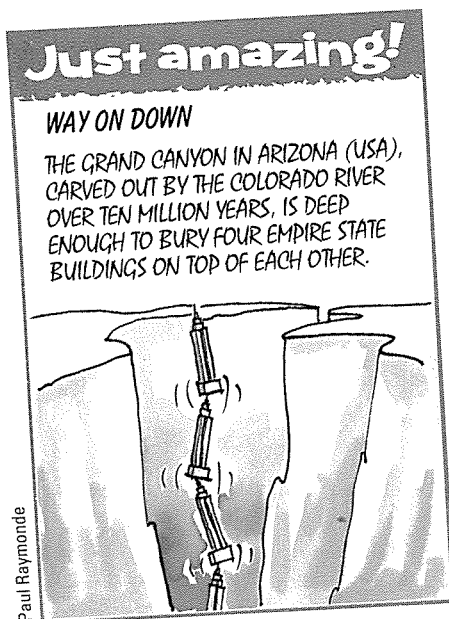
In other parts of the world, molten rock itself may rise to the surface. Spectacular from a distance, a volcanic eruption may be deadly at close range. On 18th May 1980, the top 400 metres of Mount St Helens in Washington, USA, was ripped away in a massive explosion that left 34 people dead.

Visitors to the Hawaiian Islands, in the Pacific, see displays of less violent volcanic events. These include rivers of orange-glowing lava that flow



Tony Stone Photo Library, London

down mountainsides at speeds of up to 40km/h and even lakes of lava left behind after a series of eruptions. One lake, in Kilauea Iki Crater on the island of Kilauea, is filled to a depth of 120 metres with molten rock heated to over 1000°C.



Paul Raymonde





In Malaysia, in 1988, a firework display lasted for 9 hours 27 minutes with over three million firecrackers on a display 5,723 metres long.

 GUNPOWDER

 ROCKETS

 HUGE DISPLAYS

FIREWORKS!

FIREWORKS' DAZZLING colours, sparkles, whooshes, and bangs are caused by a variety of chemical reactions taking place at high temperature. And those high temperatures are caused by one important substance – gunpowder.

Gunpowder was invented in the 9th Century AD by the Chinese who used it to make firecrackers and rockets for special occasions. Later, its explosive power was harnessed in guns and cannons.

Gunpowder is a mixture of saltpetre, carbon and sulphur. At a fireworks factory, the carbon, in the form of charcoal, is ground together

with the sulphur in a ball mill. This is a rotating drum with metal balls inside, which thoroughly crush and mix the carbon and sulphur to form a blackish powder.

Gunpowder

The carbon-sulphur mix is then added to the saltpetre in a wooden drum mixer that contains wooden grinding balls. The resulting gunpowder is ground to an even finer, more compacted blend that is suitable for use in all types of fireworks.

When gunpowder is exposed to a flame or lighted fuse, the chemical energy stored in the mixture is released. The oxygen in the saltpetre reacts with the sulphur and carbon to pro-

duce large amounts of hot sulphur dioxide and carbon dioxide gas, which expand rapidly. At the same time, the high temperature produced makes the reaction spread quickly through the rest of the mixture, causing an explosion.

The skill in making good fireworks is to control that explosion so that it can produce spectacular effects that are still safe.

Exhaust gasses

In a rocket, for example, the gunpowder is packed inside a tough case which forces the rapidly expanding hot gases through a hole in the base. As the exhaust gasses escape at high pressure, they push



The technology used to make fireworks is over a thousand years old. Gunpowder and the chemicals that produce the colours and sparks are packed into cardboard tubes. But simple firework rockets are the forerunner of those that put the Shuttle into space.



The World of Interiors

SOLID FUEL BOOSTERS

A large number of unmanned spacecraft and missiles are launched using rockets propelled by solid fuel, that are just like huge fireworks.

These large rockets, however, carry a much more potent blend of chemicals than gunpowder to give them a very powerful thrust. Britain's nuclear submarine-launched Polaris missiles, for example, are propelled by a mixture of ammonium perchlorate and polyurethane fuel.

Solid boosters also help to accelerate the American Space Shuttle. Their main drawback is that, once ignited, they cannot be controlled like a liquid fuel rocket and so cannot be used in steering 'thrusters'.

the rocket's head and drive it into the sky. A stick attached to the side helps to stabilize the rocket in flight and helps in launching.

In a Catherine wheel, the gunpowder is packed into a long paper package. This is flattened through a mangle, then wound on to a wooden spindle. A nail driven through a hole in the middle of the spindle into a post



PE Parker

holds the firework in place and the gases produced by the burning gunpowder spin the Catherine wheel around at high speed.

But gunpowder alone cannot produce the many spectacular effects of modern fireworks. These result from reactions involving other chemicals that are added at the factory.

Burning metals

The reds, whites, yellows, and greens come from burning chemicals that contain certain metals. Barium salts, for example, give off a greenish light, while those containing strontium burn a vivid, bright red.

Long slow burning fireworks, called 'lances', are used to spell out words or draw pictures against the night sky. They are nailed to wooden frames with their fuses linked in series.

The most difficult firework colour to produce is blue. Recently, manufacturers have begun to use powdered PVC (polyvinyl chloride) to create a fairly bright bluish light.

The brilliant sparks given off by many fireworks result from burning powdered metals, especially iron and aluminium. Larger particles – filings – of these metals give the appearance of glitter, shining brighter and longer.

Stars and sparks

To produce a variety of effects in the same firework, manufacturers pack together a number of different chemicals. Mixed in with the gunpowder are so-called 'stars'. These are pellets made up of layers of various metals and metal compounds. As the shells burn through from the outside, different colours and sparks unfold.

The exact mixture of gunpowder with other chemicals, how much it is compressed and the way it is enclosed all determine the rate of burning. Roman candles, for example, have a slow-burning composition.

Small fireworks have a paper fuse impregnated with a slow-burning chemical. Major displays involving hundreds of large fireworks are started with electronic ignition systems so that they can be

ignited from a safe distance. These displays are set up on metal gantries. Fuses join up the sets of fireworks.

But never forget, fireworks are DANGEROUS!

Huge explosions and showers of sparks in the sky are produced by a 10-cm shell launched from a simple pipe mortar.

Just amazing!

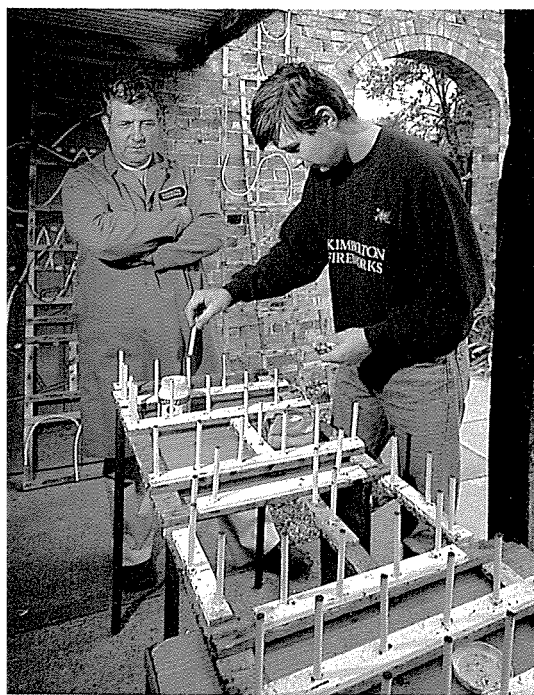
THE BIG BANG

AT A FIREWORK DISPLAY IN HOKKAIDO,

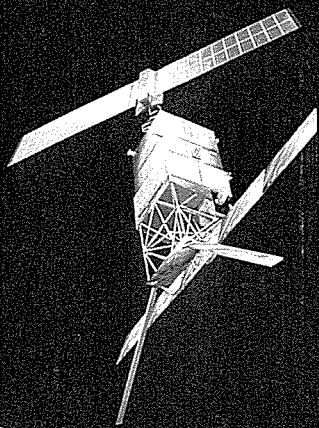
JAPAN, ON 15 JULY 1988, A 700-KG SHELL CALLED UNIVERSE I PART II WAS LET OFF. IT BURST INTO A SHOWER OF SPARKS 1200 METRES IN DIAMETER.



Paul Raymonde



- Q MAP PROJECTION
- Q TRIANGULATION
- Q AIR SURVEYS



MAP-MAKING



Earth Satellite Corporation/SPL

Satellites are used to map remote regions (far left) which are inaccessible by conventional methods. Satellite pictures of cities (left) are also used to compile street maps.

MANY PEOPLE – MISTAKENLY – believe that maps are like aerial photos of a piece of land taken on a cloudless day, with all the things shown in the right place. But because the earth is a sphere it cannot be accurately represented on a flat surface. Cartographers (mapmakers) therefore have to distort or exaggerate certain features.

Imagine that the map is first drawn on an extremely thin rubber skin that coats a geographer's globe. How could you remove this rubber skin

and lay it flat on a piece of paper?

One way is to make a pinprick at the south pole, then stretch the skin until it can be removed. Then the piece of rubber is stretched to make a flat disc. This shows the whole Earth in one circular area, but with this system (the so-called Azimuthal projection) the south pole becomes the circular perimeter of the disc.

Cylindrical projection

Another, very familiar projection is named after Mercator, a 16th century geographer. Imagine the globe is now



translucent with a light bulb inside it. A long sheet of paper wrapped around the globe, touches it at the equator. An image of the features of the globe is projected on to the paper. Tracing these features produce a map that closely resembles Mercator's projection. But now, distances become enormously exaggerated the further you go towards the poles, making

MERIDIANS

Any place on the Earth's surface can be given its own unique label by means of its co-ordinates. Lines of longitude are circles called meridians, running from the north to the south pole, dividing the globe into 360 degrees. The zero line is called the prime meridian and runs through Greenwich, in south-east London, UK. The east-west position of any place is measured as so many degrees, minutes and seconds east or west of the prime meridian.

North-south distances are measured in relation to the equator, the circle that runs around the globe halfway between the poles. Parallels of latitude are circles drawn around the Earth parallel to the equator, between the equator and the poles. Thus San Francisco's position is described as $37^{\circ}45' \text{ N}$, $122^{\circ}30' \text{ W}$. Sydney is $33^{\circ}50' \text{ S}$, $151^{\circ}10' \text{ E}$.



Wild Leitz

Greenland, for example, look bigger than Australia, when it is actually less than a third of the size.

The great advantage of the Mercator projection is that directions are accurately shown. A journey made in a constant direction – say, 17 degrees east of north – appears as a straight

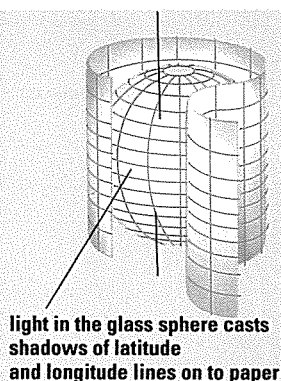
Air survey cameras are held in mounts that are designed to reduce vibration and allow the cameras to be rotated to compensate for aircraft drift caused by air currents.

line on the Mercator projection. In most other projections a line of constant direction over the globe is generally represented by a curve on the map, making an air or marine navigator's job extremely difficult.

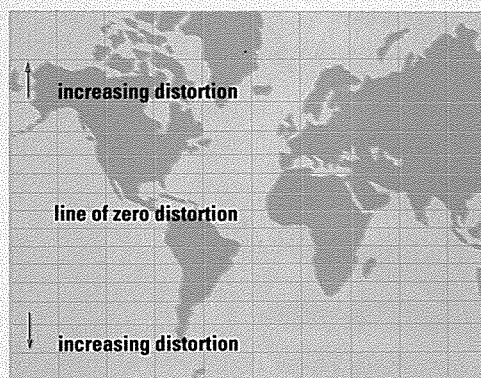
Distortion

Some distortions in maps are not forced on the mapmaker by geometry; they are introduced deliberately to make the maps more useful.

Railway passengers, for example, are not much interested in true distances and directions – they mainly want to know at which stations a particular train stops and where they

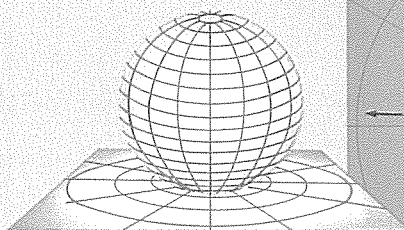


light in the glass sphere casts shadows of latitude and longitude lines on to paper



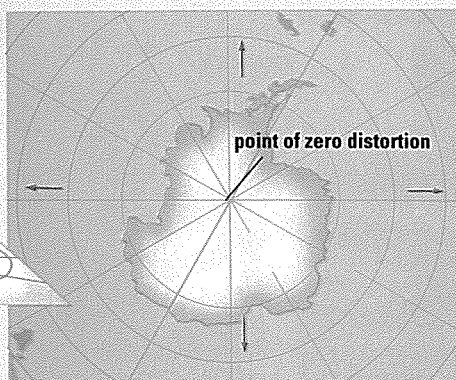
Cylindrical Projection

Spherical maps – or globes – are impractical for large-scale use, so map-makers have to portray the Earth's surface by means of various 'projections'. Cylindrical projection from the Earth's centre on to a cylinder touching the equator is widely used. Conic projections are best suited to middle latitudes.

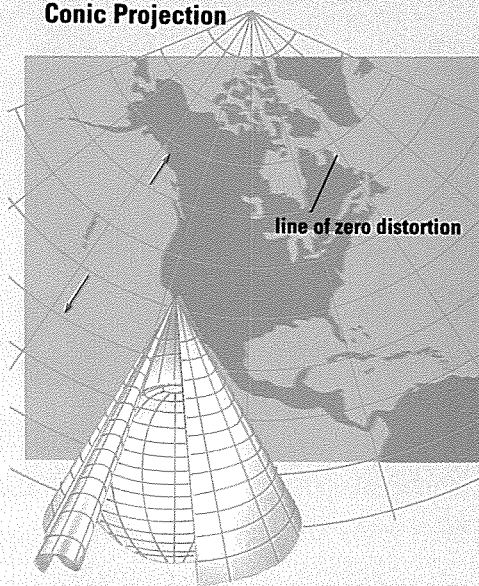


Azimuthal Projection

Mapping Techniques



Conic Projection



Surveyors use a theodolite to measure horizontal and vertical angles between the control points of the area to be mapped.

have to change trains. The map of the London Underground is a good example. Originally, the map was geographically accurate – depicting the different stations at the correct distances and showing the shapes in the lines. As the railway system expanded, however, the map became so convoluted (it was dubbed the ‘vermicelli’ map) that passengers had great difficulty reading it. On the modern map, the shapes of lines are simplified and their directions are not accurate. The widely spaced stations of the outer regions are shown as equally spaced. Motorway maps and maps of air routes often use similar simplifications.

Rubber-sheet geometry

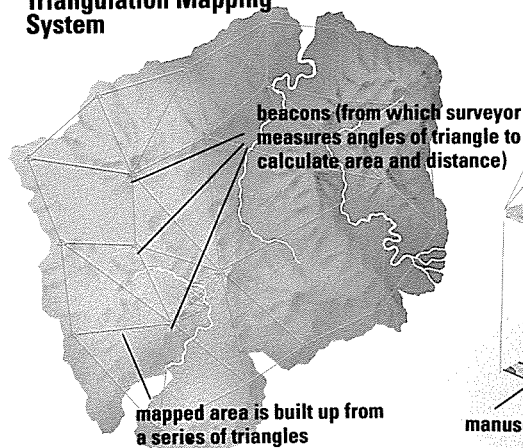
Such a map is described as ‘topologically equivalent’, which means that it depicts information by stretching and squeezing as necessary, but without tearing. Topology is often called ‘rubber-sheet geometry’. Distances and directions are altered, but the important relationships – for example, that a certain railway line



Geo/Science Photo Library

Large areas are mapped by dividing the terrain into triangles and measuring the angles with a theodolite. Aerial photography provides the data for Ordnance (Government) survey maps.

Triangulation Mapping System



two fine lines or one thick one. Colour-coding is also important. Each colour on a map is used in conjunction with lines and symbols to convey a wide range of information.

Scale

The scale of the map will be another important consideration, because this dictates the geographical coverage and the quantity of information depicted. For example, a map of the USA at a scale of 1:1,000,000 (1 cm on the map represents 1,000,000 cm or 10 km on the ground) could only depict large towns, major roads, rivers and large geographical features. But a map of California at a scale of 1:200,000 (1 cm on the map represents 2 km on the ground)

A map-folding machine – the final stage in map production. Maps are produced manually, on lithographic printing machines, or digitally – by feeding the data into a computer.

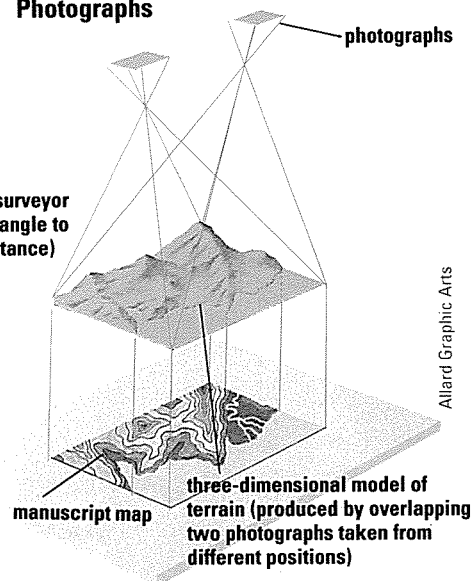
could show the complete road system, including minor roads, rivers and streams and small physical features.

Punch registration

After the planning has been completed the first ‘rough’ has to be compiled. This is done with coloured inks and brings together all of the information on one plastic sheet. To achieve the perfect alignment of detail a technique called ‘punch registration’ is used. Plastic sheets up to a maximum size of 100 x 150 cm

have a series of holes punched down one side in much the same

Making a Map from Aerial Photographs

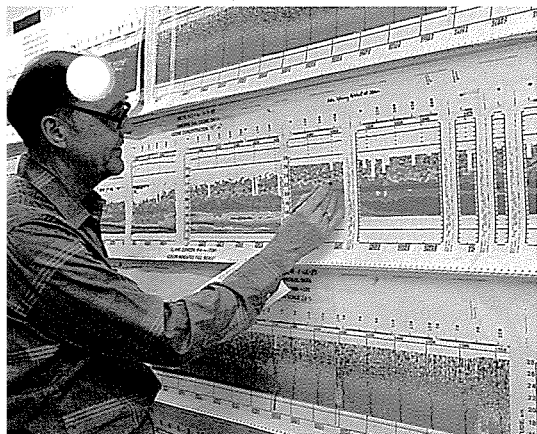


Allard Graphic Arts

manner as a roll of film. Steel pins are then inserted into the holes allowing other plastic sheets to be accurately placed on top of the original sheet. As these plastic sheets are translucent, detail can be added to the top sheet and still register with the one underneath. The sheets can be separated and replaced as many times as necessary and as long as the pins are re-inserted, registration will be exact.

The colours on a map are not all drawn on the same plastic sheet or ‘foil’. There can be as many 24 com-

MAPPING THE SKIES



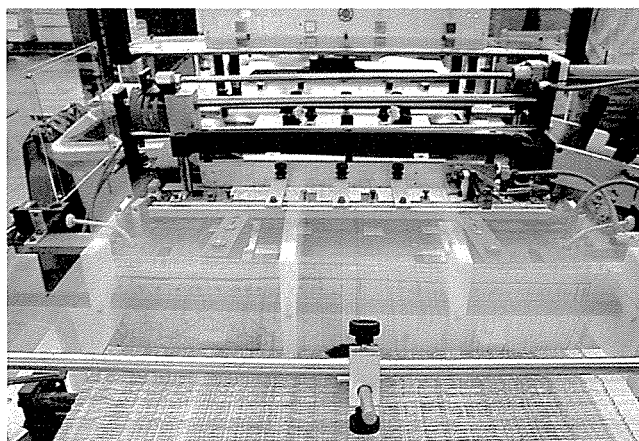
NASA Science Photo Library

NASA scientists have used the latest laser technology to produce images of the ‘holes’ in the Earth’s ozone layer. Data gathered over the Arctic by a DC-8 flying laboratory and high altitude ER-2 flights have shown a marked increase in chemicals known to destroy ozone. In Antarctica, satellite data has revealed a hole that has been growing in size and severity since 1980.

runs through certain stations in a certain order – are unchanged.

Symbols

A map’s final appearance depends upon its function. At the planning stage the mapmakers will meet to discuss how best to interpret the results of the surveyor’s work. Decisions are made regarding symbols – such as whether roads will be shown using



Ordnance Survey



ponent foils combined together photographically to produce the four final films from which the colours will be printed.

Mapmakers get their basic information by surveying – on the Earth's surface, from the air or from space. On the ground, the co-ordinates of stations are found by triangulation (the measurement of angles using

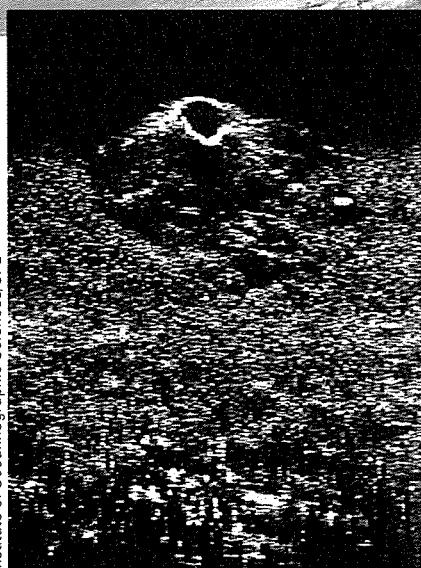
ORIENTEERING



Orienteering is a sport that tests the participant's map-reading skills. Competitors navigate their way at their own pace between features marked on a special coloured map. An orienteering course varies in length from about 2 km, with six to ten control points for beginners and children, to over 12 km for experienced orienteers. The winner is the person with the fastest time.

theodolites) or trilateration (the measurement of distances using electronic instruments).

The best mapped countries are covered with a dense network of reference points, known as beacons or trigonometrical stations. 'Bench marks' engraved in stone or metal are reference points whose heights



above sea level have been precisely measured using accurate instruments called levels.

Aerial photography

To find out the exact location of landmarks such as buildings, woods and fields, aerial surveying is by far the most rapid and comprehensive method. An aircraft criss-crosses the chosen terrain. On board is a special camera, weighing perhaps 200 kg and producing large negatives, perhaps 23 cm square. It points straight downwards and takes photographs spaced at regular intervals, as controlled by the aircraft's speed.

Stereoscope

Overlapping photographs are taken, so that every point on the ground appears on at least two pictures. Two consecutive pictures can be viewed in a machine called a stereoscope, which gives a three-dimensional view of the relief – the rise and fall of the ground. This enables the mapmakers to work out the relief and mark it on the map.

Infra-red cameras

Essentially the same thing is done over larger areas by satellites orbiting a few hundred kilometres above the Earth. The world's remotest and most inaccessible places can be rapidly mapped in this way. Infra-red cameras can show the health of vegetation

Satellite pictures of the ocean floor reveal higher mountains and deeper valleys than those found on dry land. The 1,325 km-long Philippine Trench in the West Pacific can be clearly seen in this computer image of the sea bed. The 1500-metre-high volcano (below left) was mapped by side-scan sonar. It was discovered in the East Pacific at a depth of 4,000 metres.

and the temperature of the sea; they can also chart the development of hurricanes, oil spills, and food crops.

Relief maps

In addition to showing the position of towns and countries, maps can provide information on height and depth. Height above sea level and depth below it can be shown by means of colour. Or a striking impression of the relief of the terrain can be given by shading it as if it were illuminated from a low angle. Relief and additional details such as buildings may also be represented pictorially.

Contour lines were first invented to show heights. A contour line joins points on the ground that are at the same height, but can also be used to show other types of information at a glance – about climate, population density and so on.

The future

Maps can now be made from computers, in which the data is revised daily by surveyors who feed in digitized map amendments. Moving maps, using Global Positioning Systems, may soon enable car drivers to locate their position from satellites and follow their route on a moving map.

Just amazing!

COUNTRIES IN COLOUR

IT TOOK 120 YEARS TO PROVE THAT ONLY FOUR COLOURS ARE REQUIRED TO SHADE ANY MAP SO THAT EVERY ADJACENT AREA HAS A DIFFERENT COLOUR.



Paul Raymond

PATTERNS OF

CHAOS

FINDING ORDER IN THE WORLD and explanations for complex processes has been the traditional role of scientists. Now they are being challenged with the discovery of chaos, often in what they had thought were the most orderly systems.

Man has long been of the opinion that explanations for strange and inexplicable phenomena are just around the corner; that as science progresses the mysterious will become clear. The discovery of chaos has caused a revolution in the world of science.

Chance

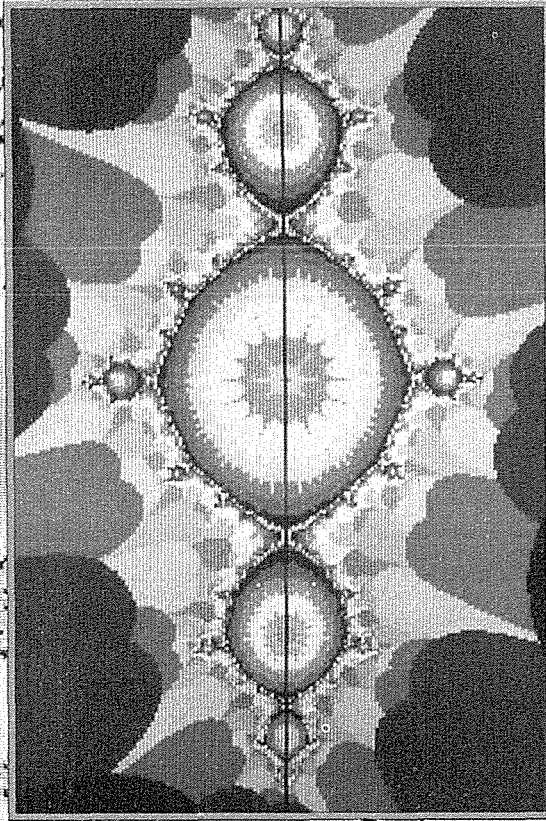
Now, rather than continuing to fill in the blanks, scientists are having to rethink some long-established concepts. Because instead of chance being an anomaly in an otherwise orderly world, the theory of chaos suggests that chance is fundamental

in the Universe. Perhaps chaos can explain, for example, why, while ocean tides rise and fall against the world's shores in an unchanging cycle, waves slap against the hull of a moored ship with an irregular beat.

Not all processes behave chaotically. But scientists are realizing that most kinds of processes do—and perhaps the most important ones.

Deterministic laws

A process that can be explained precisely by known laws of physics is called deterministic. Kicking a football or striking a billiard ball, for example, produces measurable and



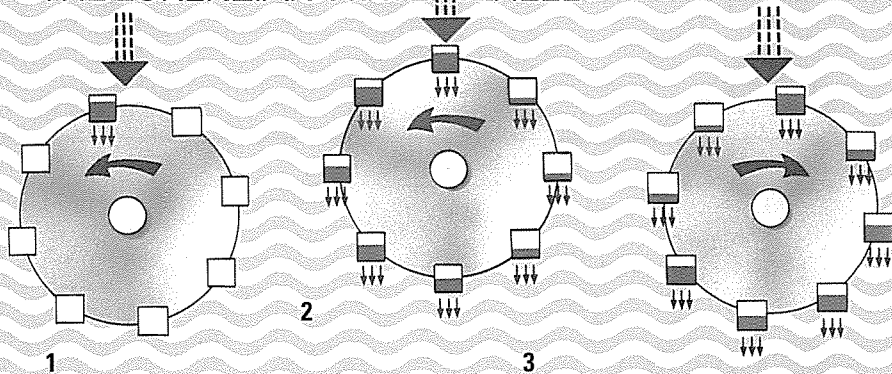
This fractal set is a fractal, a complex and fragmented shape that can be described by a single equation. It is presented on a computer screen, plotting complex mathematical functions. Strange attractors (fractal sets) are another feature of fractal geometry.



The simple waterwheel demonstrates a chaotic system:

- 1) Water pours steadily into the top bucket and its weight starts the wheel turning
- 2) The waterwheel rotates at a steady rate
- 3) As water input is increased the wheel spins faster. Each bucket receives less water and full buckets start on the upward climb before having time to empty. Thus the wheel slows down and reverses its spin. The wheel then spins and reverses itself randomly (chaotically).

THE LORENZIAN WATERWHEEL



James Gleick/Mark Franklin

predictable results. The object's motion at each and every moment is determined by its position and motion at the instant before.

Pendular motion

The new discoveries in chaos theory show that even deterministic systems can be unpredictable – the swing of a pendulum for example. The first accurate clocks relied on the regularity and predictability of a pendulum's motion. But even a pendulum not subject to chance disturbances can behave wildly – 'chaotically'.

This does not happen with a pendulum making small swings in a grandfather clock. But suppose a motor drives an arm that pushes the pendulum rod gently at a precisely controlled number of pushes per minute. When the driving rate is very close to the pendulum's rate of swing, the pendulum's motion builds up and becomes large. It is when the motion is large that it can become chaotic.

Sensitive dependence

First the pendulum swings to and fro in a straight line. Then it may begin to trace out an ellipse – a flattened circle. The ellipse may get fatter while the direction of swing changes. Then it may

Population studies of animals, birds and insects reveal the existence of chaos in ecology. The deterministic influences of the environment, such as food supply, predators and disease, do not account fully for fluctuations in population density.



get smaller while staying the same shape. There may be times when the pendulum swings in a straight line again and times when it will suddenly and unpredictably change its direction of rotation.

If the experiment is repeated from the beginning a totally different sequence will be obtained. Yet the laws that the pendulum is obeying are very simple. The varying results are caused by very slight differences in the starting

conditions from one experiment to the next – slight differences in position or in the pushes delivered by the motor. These differences are far too slight to be measurable and yet they can alter the end result dramatically. This phenomenon in the theory of chaos is dubbed 'sensitive dependence on initial conditions'.

Population trends

But chaos is not confined to physics. Ecologists use it to explain the fluctuations in density of animal populations. A simple model of population affected by deterministic laws assumes that the greater the density of population, the greater the number of births. Thus if a population doubles, the number of births doubles and if a population trebles, the number of births trebles, and so on.

With this simplified model, if birth rates are too low, the population will die out. If the birth rate is increased the population will grow, fast at first and then more slowly, until it reaches a fixed value. Chaos emerges when the birth rate is pushed higher still. Then the population increases to a

certain value, falls to a lower one, then grows to the previous value, then decreases again – flipping back and forward between the two values. If the ratio of births to deaths goes even higher the population level becomes completely chaotic. It jumps between high, low and intermediate levels –

Owen Newman/Oxford Scientific Films

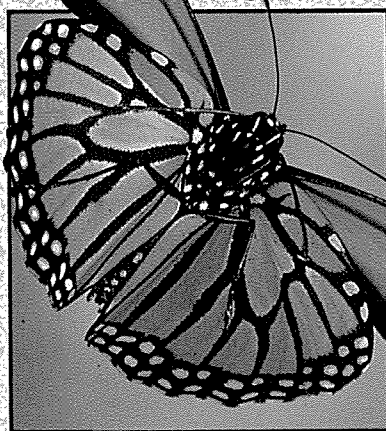
THE BUTTERFLY EFFECT

In 1960 Edward Lorenz, research meteorologist at the Massachusetts Institute of Technology, was trying to forecast weather behaviour using a computer.

Lorenz was trying to speed up the computer's working by 'rounding off' his figures – writing .452 instead of .452311 for example. He had assumed that this tiny modification could have little effect on his results. In fact, Lorenz discovered it altered the results greatly.

Lorenz found that minute differences in initial conditions – temperatures, pressures or wind directions – can have dramatic knock-on effects. This 'sensitive dependence on initial conditions' means that whenever weather is chaotically affected, long-range weather forecasting will be unreliable.

This phenomena has been called the butterfly effect because it suggests a



butterfly beating its wings in Brazil today could cause a hurricane in Paris next month. The butterfly effect has come to epitomise chaos theory.

Stephen Dalton/NHPA



with no pattern appearing and no final equilibrium being reached. In this example chaotic variations could be due to, and affected by, perfectly deterministic processes governed by simple fixed laws.

A chaotic process that may be less dependent on deterministic laws is shown in a study of the measles

scope, the surface will appear rough and mountainous. A far more powerful electron microscope will reveal another mountainous terrain on a still smaller scale.

Repeated patterns also appear commonly in branching forms. Tree trunks, for example, become branches that become twigs. On the twigs

gives the tree stability against the wind. Thus branching is fundamental to the life of the tree.

Branching forms

Branching is used also in the design of the human body. Blood, for example, is carried very effectively to and from all parts of the body by a branching system of blood vessels in ever-decreasing sizes. A small cut anywhere on the skin surface will cause bleeding, and yet the blood and vessels make up only about five per cent of the body's mass.

Another comparison can be made with the intricate branching of windpipes in the lungs. The body's ability to absorb oxygen is proportional to the surface area of the lungs. The surface area of an adult human's lungs – if they could be laid out on a flat surface – would cover an area greater than that of a tennis court.

Heart flutterings

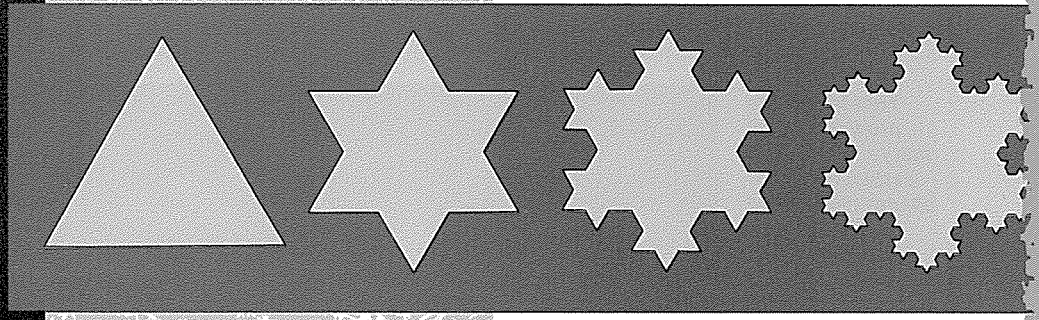
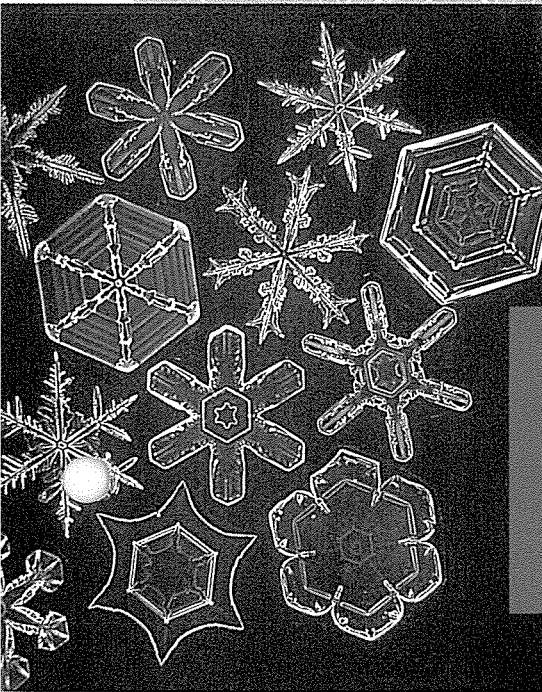
Chaotic behaviour, as well as structure, is being found within the human body. It has long been assumed that a steady heartbeat is a sign of health and that fluctuations are a sign of illness. But closer study

AN IDEAL SNOWFLAKE

The Koch 'snowflake' was first described by Swedish mathematician Helge von Koch in 1904. The core shape is an equilateral triangle. On the middle third of each side, another triangle is added – one third the size of the original. The process is repeated for the

new triangles. The resultant shape looks like a snowflake. Theoretically it is possible to continue adding triangles indefinitely. Interestingly, while the outline of the Koch snowflake is infinite, its area remains less than the area of a circle drawn around the core triangle.

Snow crystals (left) are made up of water molecules arranged with two hydrogen atoms at an angle of 105° to one oxygen atom. The fixed shape of this molecule means that a stable crystal forms only when arranged as a six-branched figure. Despite this hexagonal symmetry each snowflake is unique. Because their growth is influenced by so many factors, conditions are never identical for two snowflakes.



Sauer/ZIFA

epidemic among schoolchildren. As expected the infectious disease spreads more rapidly when children return to school after a summer break. Also as expected, the epidemic is shown to be checked by programmes of inoculation.

Chaotic infection

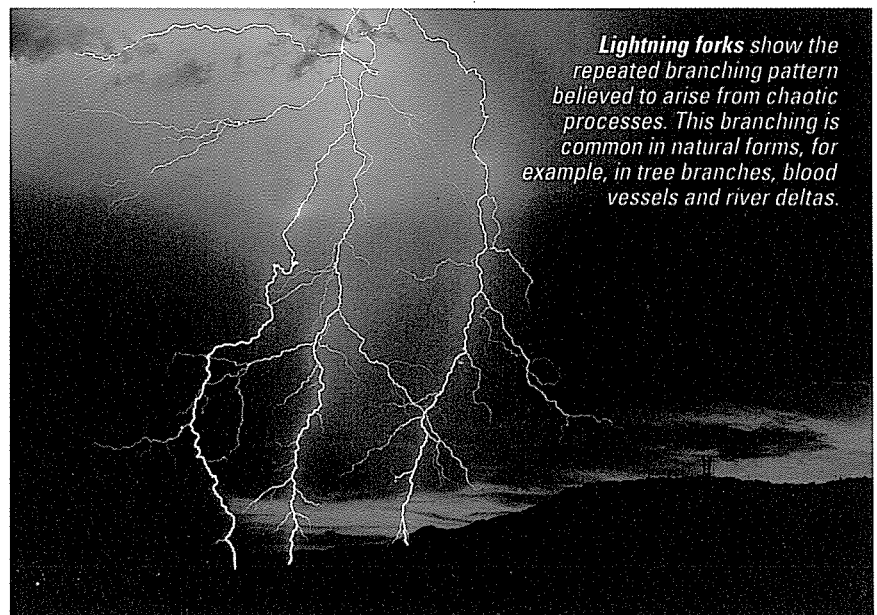
But despite these deterministic trends, the number of children that develop measles from one year to the next follows a somewhat chaotic pattern. If in one year many children develop measles, the following year tends to have very few cases. After an average year, follows a year of a similar number of cases. And after a year of very few measles cases even a general trend is difficult to predict.

Repeated patterns

In nature chaotic processes often create patterns. Viewed from a satellite, the hills and mountains of Earth form a rough pattern. Standing on a mountainside, you will see rough terrain with humps and boulders. Looking at a boulder under a micro-

scope, the pattern is taken up by the leaves. Thick veins on leaves branch into smaller veins that branch into yet smaller veins. The spreading out of the tree 'body' in this way helps the leaves capture more sunlight and

shows that in healthy bodies, heart rates vary continuously and chaotically. Although the average adult pulse rate may be, say, 60 beats per minute, this can change by as much as 20 beats per minute in just a few seconds. In the hours or days before a heart attack, the pulse rate of a patient



Lightning forks show the repeated branching pattern believed to arise from chaotic processes. This branching is common in natural forms, for example, in tree branches, blood vessels and river deltas.

Tony Stone Photo Library, London



PROFILE

TERMS

Chaos	the mathematical science of unpredictability
Fractal geometry	the study of irregular and fragmented shapes
Mandelbrot set	the most complex and important fractal discovered to date
Strange attractors	points around which chaotic systems revolve

Chaotic chemical changes in this shallow dish show as circular waves radiating from point sources of an unknown nature (possibly dust particles). The waves cancel each other out on collision. Although the waves travel at a uniform rate of several mm per minute, the patterns that they make are unpredictable.



Dr Arthur Winfree/SPL

may, paradoxically, become steadier.

Surges of electrical activity in the nervous system often seem to be chaotic. So do the levels of hormones – chemical ‘messengers’ that are released into the bloodstream to control bodily processes.

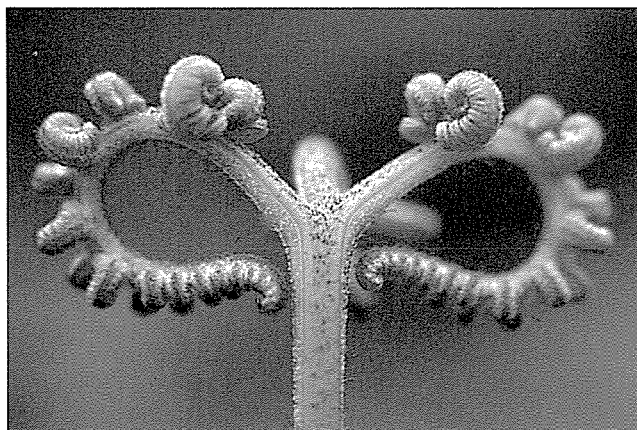
Fractals

Fractals and other repeated patterns are believed to arise from chaotic processes. They can be modelled in two-dimensions on computer by mathematical curves called

fractals. The Koch snowflake is one example.

One advantage of modelling fractals on computer is that their detail can be magnified indefinitely. A smaller fraction of a form can always be found beyond the one on screen. If you zoom in on any part of a fractal curve, the detail looks just the same as it does on the larger scale. Some fractals show wild, beautiful patterns, in which the eye cannot gain a resting place – every point breaks up into more complexity, and more detail

Fern leaves are programmed by nature to grow in a certain way. Leaf shapes can also be produced by computer with a random number generator choosing the co-ordinates. The randomness in such an exercise suggests that nature's own laws are chaotic as well as deterministic.



Claude Nuridsany & Marie Perennou/SPL

CATASTROPHE



Gamma/Frank Spooner Pictures

The theory of catastrophe describes systems that undergo abrupt changes as a result of smooth alterations to their situations.

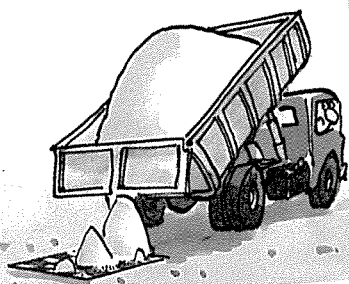
Using mathematical models, the theory describes, for example, the point at which water boils, stock markets crash and buildings collapse. Catastrophe theory has been used to describe and even to predict the outbreak of a riot in a crowd of people. It is concerned with less complex systems than the theory of chaos.

important thing about the Mandelbrot set is that in magnifications of its detail, representations of the original image can be found. This self-similarity offers scientists hope of finding order within chaos and an understanding of fractal geometry.

Just amazing!

DOUBLE-UP

IF YOU COULD PUT ONE GRAIN OF RICE ON THE FIRST SQUARE OF A CHESSBOARD, TWO GRAINS ON THE SECOND, FOUR ON THE THIRD ETC. THE END WEIGHT WOULD BE GREATER THAN THE ANNUAL WORLD RICE PRODUCTION.



Paul Raymond

beckons just beyond the visible.

Determining whether a system is chaotic, means finding the shape of its ‘strange attractor’. Strange or chaotic attractors are a feature of fractal geometry. They exist in three-dimensional space but, like fractals, can be represented graphically by computer.

The Mandelbrot set

The images first produced by the mathematician Benoit Mandelbrot in 1979 are especially spectacular. They are an example of wildly swirling patterns produced by a computer from simple fixed rules – of chaos emerging from order. The Mandelbrot set is the most complex fractal discovered to date. Like other fractals it is created on computer using complex number co-ordinates.

A number is described as complex when it is made up of two parts – one real and the other imaginary. The im-



SPEEDING PLOUGH

MECHANIZATION HAS marched on the farm, continuing to speed operations and increase yields in every area of production from ploughing the field to milling the grain.

Most modern farm tools are powered by tractor. These are the power houses of agriculture. Today's tractors have a cab that resembles the cockpit of a small plane. They are sound-proofed and air-conditioned so that the driver can work long hours without fatigue. The air vents are filtered so that the cab is dust-free. The windscreen is tinted, the driver's seat as comfortable as any armchair and the steering column fully adjustable - it is both telescopic and tiltable.

Shuttle transmission

Many new tractors have computer displays, giving the driver instant monitoring of all the working parts and hydraulic systems. Brakes and clutch are self-adjusting to minimize the maintenance time that would keep this vital farm tool out of use. And the gearbox - which often boasts as many as 18 forward gears and nine reverse gears - has special systems like a shuttle transmission to make it easier to operate. This allows the driver to switch quickly back and forth between a forward gear and a reverse.

The new generation of

The modern combine harvester is more than a cutting and threshing machine. It is a grain factory on wheels that has brought computer technology into the wheat fields.



Alex Bartle/Science Photo Library



tractors pull – and power – a range of modern ploughs, harrows and seed-drills. Almost all have been updated to meet the need of modern, mechanized farming.

Reversible ploughs

The age-old plough – a simple twisted blade dragged through the soil – has been modernized to a highly efficient tool. Modern ploughs can cut up to seven furrows at a time, using two sets of blades that can be reversed hydraulically so the farmer can plough either way up and down the field.

Some ploughs have rotating discs between the blades which help break up heavy soils like clay. Old-style ploughs would simply turn over a single long cut, leaving the earth in solid clods, while the new rotating-disc ploughs are designed to fragment the soil in several furrows, making cultivation both easier and quicker.

Powered harrows

Some modern harrows – the tools that further break up the soil ready for planting – are powered too. Knife blades, 30 cm long, are twisted as they are pulled through the soil and a roller covered with blades follows behind to help crumble the soil. Other modern harrows use the old disc system, where disc blades simply rotate as they are dragged across the soil. But modern disc harrows use two



The power house of the farm is the tractor. Inside (above) the emphasis is on comfort and ease of control.



rows of discs – one smooth, one serrated – at an angle to each other, which churns the soil more efficiently. This type of harrow is also used for burying weeds and other waste, leveling land and thoroughly mixing chemicals into the soil.

Today's seed-drills have an array of small blades to cut through the soil

and drop or blow seeds into the furrow. At the back of the drill unit is a comb harrow that brushes the soil back over the seed. However, a new type of seed drill has just been developed. This uses an arrangement of 38-cm diameter wheels which have radially extendible 'dibbers'. The seeds are fed out to the edge of the wheel and the dibbers extend to make a hole and place the seed precisely at the right planting depth.

Giant gantries

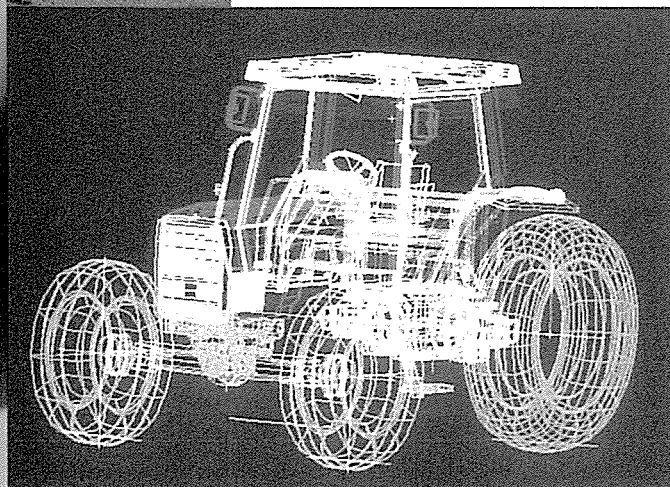
Currently, these farm tools are all pulled and powered by tractors, but the tractor itself could be on its way out. Despite their wide wheels, tractors still compact the ground where they drive and they destroy crops under their wheel tracks. So types of gantries, like those already used in horticulture, are now making their appearance in farmers' fields.

Gantries are incredibly wide machines – 12 to 15 metres from side to side – with a driver's cab on one end. Between the two sets of wheels on either end runs a long framework of struts and girders about 2 metres off

A tractor rolling off the assembly line is the product of a huge amount of hi-tech engineering. This begins on the screens of the computer-aided design systems (below). Every detail is worked out on screen (below right) before a prototype is built.



Massey-Ferguson



Massey-Ferguson

Massey-Ferguson



A gantry runs up and down the same tracks in a field, to minimize the amount of crop wasted under tractor tyres.

and straw. Eventually, it ends up in a grain tank at the bottom of the harvester. Then, when a trailer is brought up alongside, it is pumped out of a long pipe that sticks out of the side of the harvester. This way the grain can be removed without stopping the combine harvester.

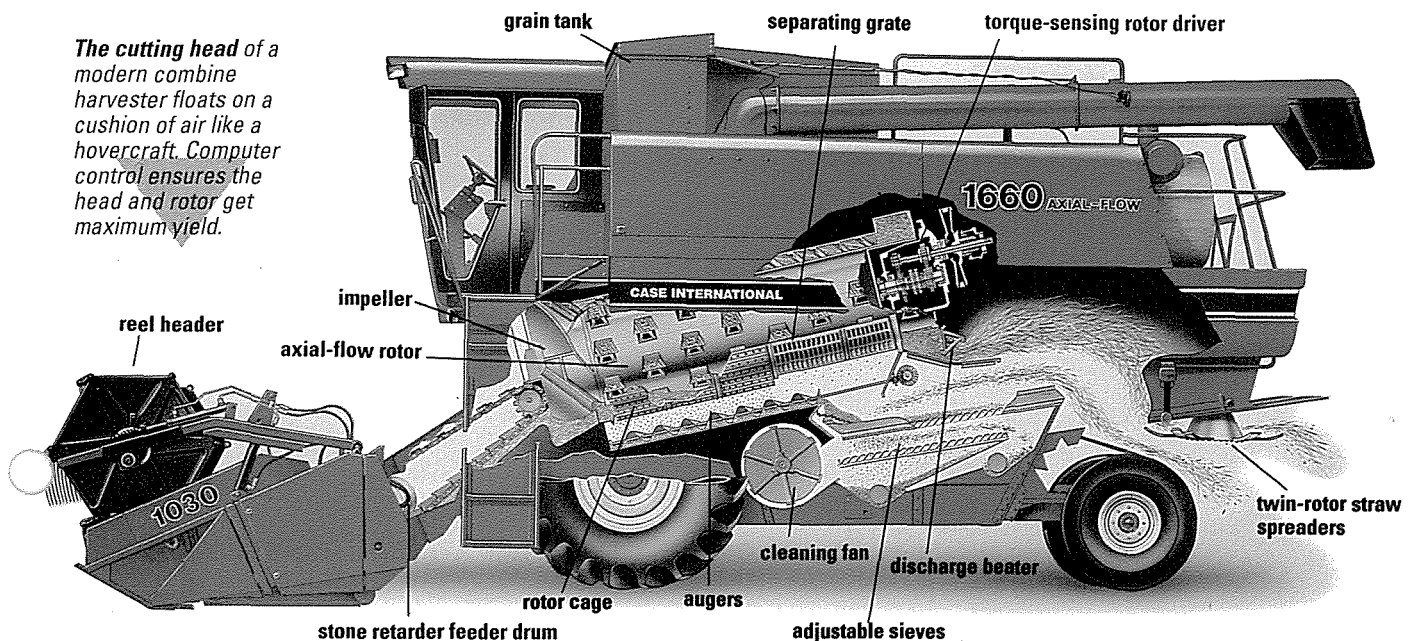
Computing yields

The on-board computer will display the drum speed, the grain loss, the cutting height and details of the yield so that the operator can adjust the speed of the harvester, the height of

the ground. Ploughs, seed-drills, harrows and other tools are suspended underneath the gantry. The advantage of using a gantry system is that only the narrow strip of soil where the wheels run is compacted and, if the

the grain from the straw. The grain pours down through a wire sieve under the thresher. The straw is passed on and tipped out of the back of the harvester to dry on the field until it is ready for baling.

The cutting head of a modern combine harvester floats on a cushion of air like a hovercraft. Computer control ensures the head and rotor get maximum yield.



gantry is run up and down in the same tracks every time it is used, only a very small proportion of the field is lost to cultivation.

Combine harvesters

The giant of the fields, the combine harvester, is like a tractor with the agricultural tools – a cutter and a thresher – built in. A computer controls the major functions. All the driver has to do is tell the computer what type of cereal it is harvesting and the harvester does the rest.

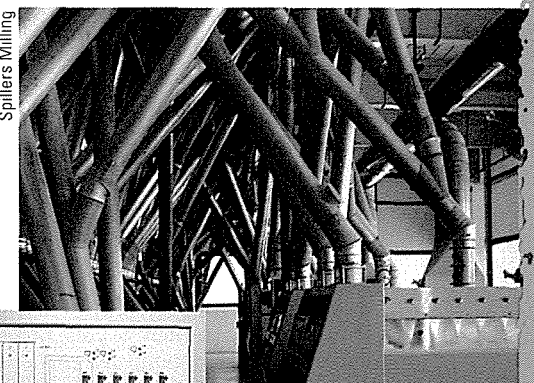
The cutter head is hydraulically controlled so that it stays a constant level above the ground. On hilly areas, a self-levelling system is used, which floats the cutter on a cushion of air in front of the harvester like a hovercraft. The air flow is controlled by the on-board computer to keep the cutting blades at the optimum height for each crop. The cut cereal is then drawn up a conveyor belt into the body of the machine where it is threshed.

Threshing cylinders

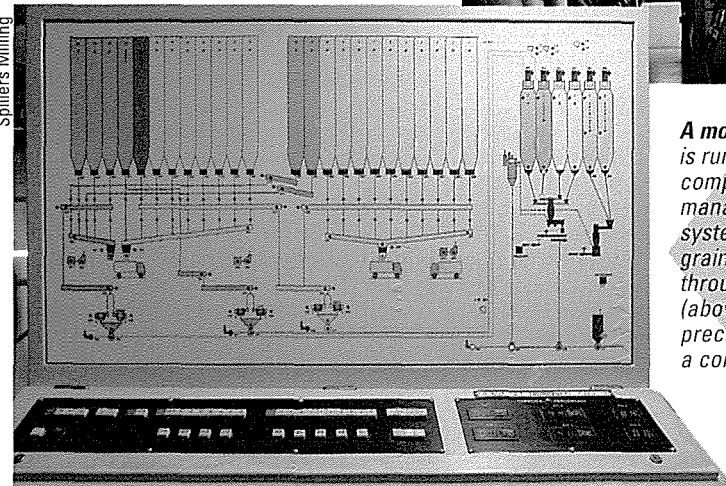
The thresher is a cylinder, usually mounted across the path of the straw conveyor. Ridges on the cylinder tear

Newer combine harvesters have the threshing drum along the path of the straw. Instead of ridges, the cylinder has raised bumps on it. These run in a spiral and drag the straw through the thresher. Again, the separate grain falls down through a wire mesh, while the straw is tipped out of the back.

The grain goes on through another series of sieves and cleaners to move the last of the unwanted chaff, dust



A modern flour mill is run by a computer management system. Different grain is channelled through pipes (above) and mixed precisely to ensure a consistent output.



ROBOT GARDENER

In horticulture too, modern computer-driven machinery is taking over from old-fashioned hand tools. Machines for repotting plants automatically have been developed and robots are moving into the market garden. Until now, the various complex operations involved in the propagation of a commercial quantity of plants by tissue culture techniques had to be performed by hand. Now though, computer imaging systems can examine plant cultures and direct a cutting tool to dissect them in the appropriate places. A robot planting tool can then pick up the pieces that can be used for propagation and place them in the growing medium – leaving the microplantlet uncontaminated by fingers, green or otherwise.

Massey-Ferguson

high-density straw wafers. Wafered straw can be used as bedding or for fuel just like regular straw, though it is only half the bulk.

The last – and biggest – machine used in the business of handling grain is the flour mill. When grain arrives at the flour mill, it is first tested to make sure that it is up to standard and that it has not yet begun to sprout. Next it is cleaned. Huge magnets remove ferrous metal objects. Shape graders separate oats, barley and smaller seeds from wheat. Gravity separators remove stones. Air blasts out dust

A hay baler has two sets of belts running in opposite directions, which roll the bale. When it has reached full size, the tailgate opens and the bale is ejected. A simple device, the baler is powered by a tractor (below).



and chaff. Then the grain is softened by adding water.

Once the wheat has been properly cleaned and conditioned, it is blended with other wheats so that the flour that comes out of the mill has a consistent quality day after day.

The blended wheat – or grist – is then passed through a series of fluted 'break' rollers which rotate at different speeds. These are set very precisely so that the wheat is not crushed but sheared open, separating the white insides from the outer, brown, skin.

The result is passed through an arrangement of sieves known as a plansifter and over a sieving table known as a purifier. The white flour – known as semolina – is channelled through a series of smooth reduction rollers for final milling to flour.

Break rollers

The coarser bran with white starch still attached will go back to a second break roller, to separate the white from the brown. In a typical modern flour mill there will be up to four break rollers and 12 reduction rollers. These lead to 16 flour streams, a bran stream, a wheat germ stream and a bran/flour/germ wheatfeed stream.

The whitest flours come from the earliest reduction rollers. The flour

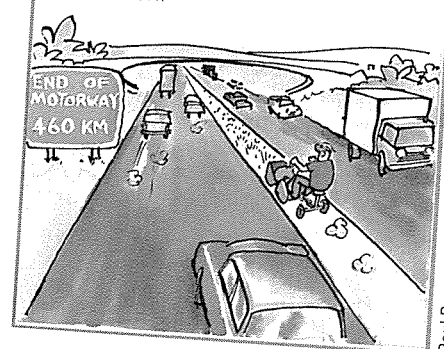
gets less white from the later rollers as the proportion of bran increases.

White flour is used for baking. Wholemeal flour is produced by re-blending bran, wheatgerm and white flour. Excess bran is sold to make breakfast cereals. And wheatgerm is sold to healthfood stores.

Just amazing!

ONE MAN WENT TO MOW...

BARRY, TREVOR AND ANDY STEMP DROVE A LAWN MOWER 460 KM IN 12 HOURS IN A COMPETITION ORGANIZED BY THE BRITISH LAWN MOWER RACING ASSOCIATION.



Paul Raymonde

the cutting heads and the rate of rotation of the thresher if necessary. The computer stores typical yield details for various crops, so the yield of any field can be instantly compared. The computer also monitors the performance of the combine harvester's engine, its fuel and coolant levels, fan speed and the level of the grain tank.

Grain stripping

A quicker alternative is now being developed though. It is called grain stripping. Instead of cutting the cereal before threshing the grain, it simply threshes the grain on the stalk and leaves the straw behind standing in the field. Later it can be ploughed back into the soil, burned off or cut and baled if the straw is needed.

But straw is bulky and storing it is a problem. One solution now under study is straw 'wafering'. The straw is cut and drawn up a conveyor belt to two interlocking cog wheels. These dice and compact the straw into small





BACKHOE LOADERS



COMPACTERS



RIPPERS

BIG DIGGERS



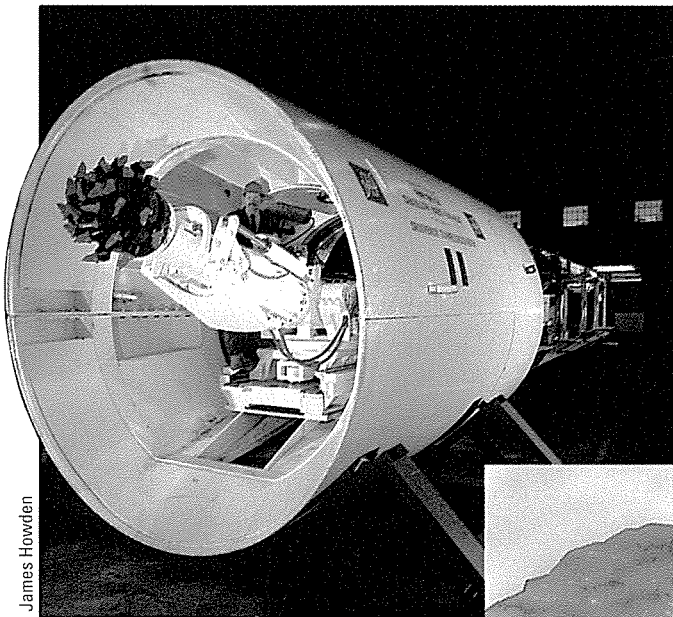
Giant bucket wheel excavators – weighing 13 000 tonnes – can move up to 110 000 cubic metres of coal or earth every day. Each bucket (on left of picture) is large enough to hold a small car. The machines are so big that they have to be built on site.

THE MAMMOTH TOOLS THAT are used in major construction projects enable Man to perform engineering miracles that would have taken earlier civilizations scores of lifetimes to achieve. Nowhere is this more evident than in roadbuilding and tunnelling. To lay a road, the terrain first has to be levelled off. In rocky or mountainous areas, major obstacles have to be broken down. On heavily compacted soil or flat rocky terrain, giant rippers

are sent in. Each one drags a huge metal hook through the ground to smash through large rocks and loosen the earth. The hook is attached to an hydraulic mount so that it can be forced into the ground at the beginning of its run and lifted out at the end. When this is completed, it is time to send in the bulldozers.

Bulldozers come in various shapes and sizes. Some have huge wheels with massive pneumatic tyres to help with the rough terrain. But the first bulldozers to be used, to clear trees





James Howden

A micro-tunnelling machine, 3 metres in diameter, used for creating sewage systems. The tungsten carbide cutter head can be changed for a digging bucket (right) according to the type of soil being bored.

and the top soil, have tank tracks instead of wheels to give them better traction on the ground.

Bulldozers have a flat or only slightly curved blade, which can only be lifted a little way off the ground for transportation. This blade is used for pushing debris into heaps, roughly scraping away the top soil or pushing over trees on the site.

Some bulldozers – known as harvesters – carry other attachments instead of blades to rip trees up by the roots or shear them off at ground level. Where digging has to be

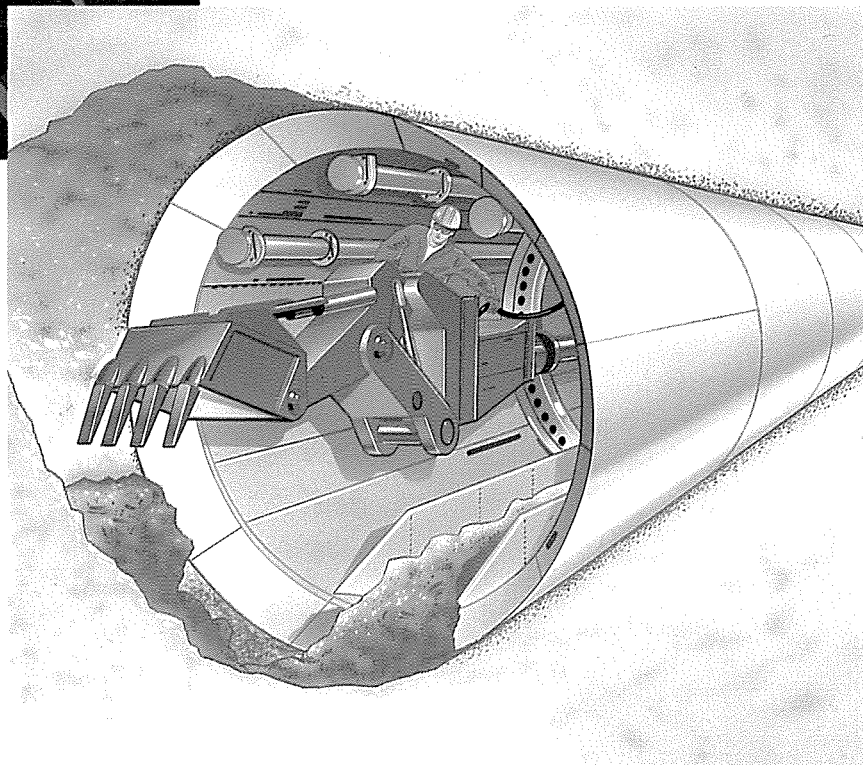
Surface mining machines remove rocky, compacted ground covering coal and other mineral deposits. These machines can remove up to 14,000 cubic metres of earth every hour. The bucket wheels can be equipped with flat or round-shaft cutters depending on the material to be excavated.

done, massive excavators are brought in. Again mounted on caterpillar tracks, these carry huge articulated arms with a large bucket-shaped shovel on the end. The arm has three sections, each raised and lowered by a large hydraulic ram. A further hydraulic ram turns the shovel so that it can scoop up rubble.

Swing system

The shovel, arm and cab of the excavator are mounted on a swing system. This is a huge cog, which will swivel the cab on its superstructure so that the shovel can be used to dig at the side of the excavator and be-

Krupp Industrietechnik



James Howden/Joe Lawrence

hind it, as well as at the front.

Although excavators can be used to shovel earth directly into trucks, usually a small loader is used. This looks much like a bulldozer, but instead of a blade it carries a bucket-shaped scoop that can shovel up a large quantity of loose debris. The scoop is then lifted on hydraulic arms so that the contents can be tipped into the back of a truck.

Hydraulic digger

So-called backhoe loaders have a second hydraulic arm at the back that carries a small excavator shovel so that it can dig as well as dispose of the debris. It also has hydraulic legs that



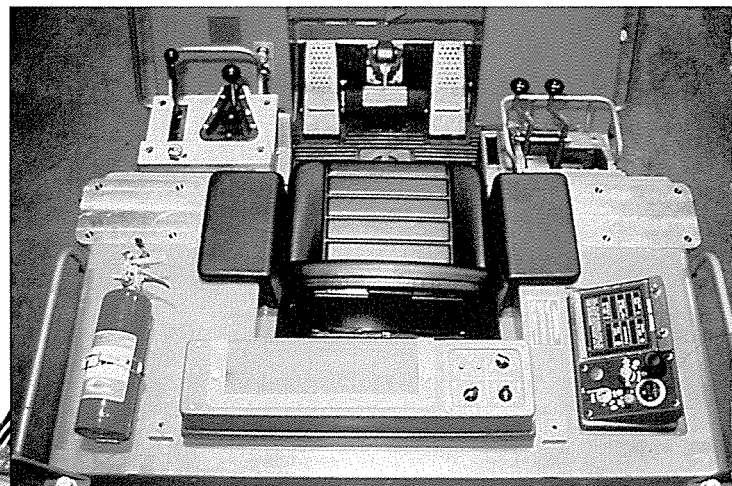
Caterpillar

Impact rippers have a forged alloy steel shank that can shatter even the hardest types of rock. Excavation machines are constructed on a production line (left).

when loading. The suspension rides on compressed nitrogen to dampen the shocks that occur when riding over rough tracks.

Once the road bed has been cleared and excavated, huge scrapers level the surface. As well as smoothing off the existing surface, they spread aggregate, gravel and sand evenly across the road bed.

The gigantic Demag H 485 mining shovel can fill a 154-tonne truck with only three bucket loads. The operator steers the vehicle with two pedals that are situated at the front of the driving cab (right).



Caterpillar

A compactor is then brought in to compress the road bed to give a solid foundation for the road itself. These have a series of wheels - usually three at the front and four at the back, so that they overlap. The tyres are smooth and pneumatic to even out pressure.

Then the huge 'paving train' moves in to lay a top surface of concrete or tar. Most roads are topped with tar, but some motorways are given a tough concrete surface to withstand the constant battering they receive from heavy traffic. Once the surface has been laid, a compactor is again used to smooth off the sur-



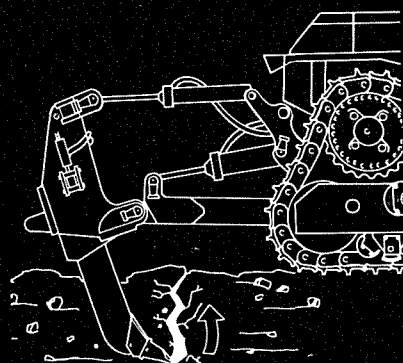
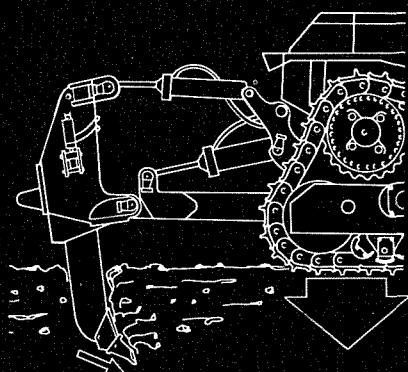
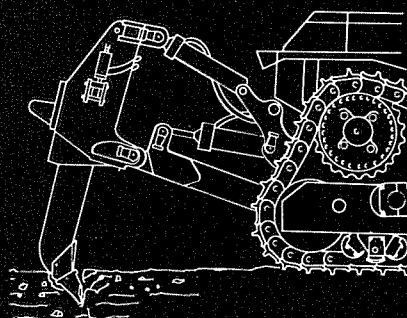


tunnel's liner to be dropped in. The drive unit is then restarted and the hydraulic jacks push the liner into the tunnel as the crushing head sinks deeper into the soil. Each time the drive unit reaches the end of the pit and the liner has completely disappeared, the jacks are released, the drive unit moved back, a new section of liner is dropped in and the whole process repeated.

Laser beam

To make sure the tunnel is going in exactly the right direction, the tip of the pilot tube is steerable. A small mirror target hangs down from the roof of the static part of the tube and a laser theodolite sends a beam down

Hydraulic excavators are used to remove topsoil in preparation for major construction projects – in this case the Channel Tunnel. They can be fitted with huge magnets and a variety of booms depending on the size of the job.



THE CHANNEL TUNNEL

Workers digging the Channel Tunnel used tunnelling machines with a massive cutter head, equipped with 85 tungsten carbide picks. This rotates at up to 4.5 revolutions per minute and advanced in 'cuts' that are 1.5 metres deep. Each one of these cuts generated 86 tonnes of spoil, or excavated earth, that was carried by a conveyor belt directly from the cutter to the rear of the machine. There it was discharged into skips and transported out of the tunnel by truck or train. Once each cut was completed, a concrete ring was constructed behind the machine's shield. The ring came in segments. The three lower sections were dropped into position by a crane and the three upper segments were positioned by an erector. Tunnellers advanced more than 162 metres a week.

face, but this time a sprinkler system sprays water over the wheels, cooling them as they level off the hot tar.

In the case of tunnelling, several different methods are employed, depending on type of soil and the length and breadth of the tunnel. In the case

The shank of a ripping machine first thrusts downwards into the ground. The tip is then pulled backwards, exerting pressure by levering against the weight of the machine. The increasing pressure fractures the rock.

of smaller tunnels, a huge drill is used which has a revolving 'crushing head' that bores through soil and rock. The stem of the drill has a spiralled flange that draws debris back down the shaft and mud is pumped through the tunnel to cool the crushing-head and flush debris out of the system.

Pilot tube

The crushing head is enclosed in a pilot tube, which is lowered on to a guide frame in a starting pit along with a drive unit. Behind the drive unit, a concrete or steel wall is constructed. Huge hydraulic jacks are braced against the wall, forcing the drive unit down the guide frame and the drill bit through the ground. When the pilot tube has completely disappeared into the tunnel, the jacks are released and the drive unit moved back down the guide frame, allowing a section of the

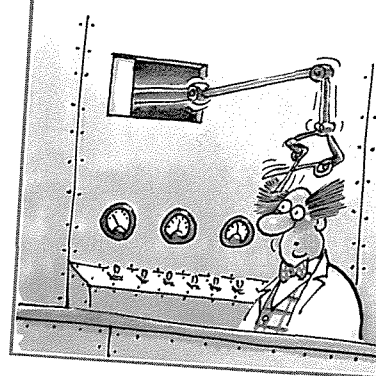
the tube. This is reflected off the target and back down the tube where it is displayed on a screen. There, any deviation in the tunnel can be spotted and the steerable tip can be turned to move the tunnel back on course.

Coal

Just amazing!

CUTTING IT FINE

A \$13 MILLION OPTICS DIAMOND MACHINE IN CALIFORNIA, USA, CAN SEVER A HUMAN HAIR 3,000 TIMES LENGTHWISE!



Paul Raymond



THE DOLDRUMS



THE GULF STREAM



WHIRLPOOLS

THE COMMANDING

CURRENTS

CURRENTS ARE THE DRIVING force of wind and water around the world. They play a crucial role in determining the climate, as well as the routes taken by aircraft and ships. Powerful, rotating currents can also pose a deadly threat in the form of tornadoes, hurricanes and whirlpools.

The Earth's atmosphere is kept in constant motion by the uneven heating of its surface. At the tropics, warm air rises above the Sun-drenched equator and moves off towards the poles. Cold air at the poles sinks and moves towards the equator. In between is a temperate zone of rising and sinking air.

Because the Earth spins on its axis, these north and south movements of air are deflected. Winds are diverted to the east in the northern hemisphere, and to the west in the southern hemisphere. The global circulation of air is then further complicated by mountain ranges and the fact that the sea gains and loses heat more slowly than the land.

Trade winds

Although the wind strength and direction at any one place varies a great deal, the general circulation of air around the Earth is fairly predictable. The trade winds, for

Huge, swirling currents of air form themselves into massive cyclonic storms. The most destructive of these, hurricanes, boost winds of over 300 km/h and can be 1,600 km across.

The Sargasso Sea is at the centre of the circulating waters of the North Atlantic. The sea takes its name from the floating sargassum seaweed that collects in the still waters there.

example, blow steadily westwards from the sub-tropics towards the equator. Where the trade winds meet is a band of still, equatorial air known to early sailors as the doldrums.

To the north and south of the trades are two other belts where there is often little wind. These are the horse latitudes, so called because sailing ships becalmed there, in blazing heat, would throw their horses overboard. At still higher latitudes are the westerlies, bringing warm air from the

southwest in the northern hemisphere and from the northwest in the southern hemisphere.

The 'Roaring Forties'

Large continental land masses in the north disrupt the westerlies and cause them to vary in strength and direction. But in the south, where there is more open ocean, the stronger westerlies have earned themselves the name the 'Roaring Forties'.

Winds, together with tides and the

Tony Stone Photo Library, London

Oxford Scientific Films



Sun's heat, also play a major role in creating ocean currents. In general, ocean currents move in the same way as the world's major wind systems.

Ocean gyres

Geographers have identified around 40 important currents in the ocean surface. Many of these link up into five giant loops of moving water, called gyres, that circle the various oceans. For example, the North Atlantic gyre starts north of the equator where trade winds and the Earth's spin steer the North Equatorial Current west towards northern South America. This current's water joins the Gulf Stream – a warm ocean river over 600 metres

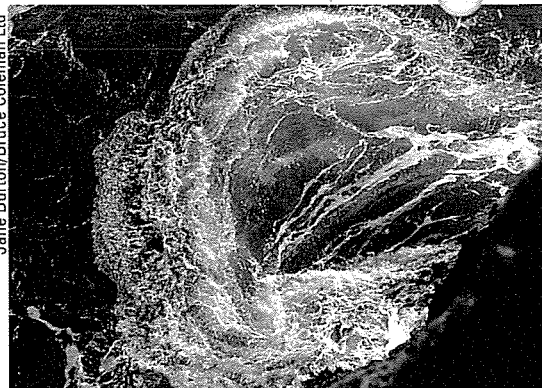
Paul Williams



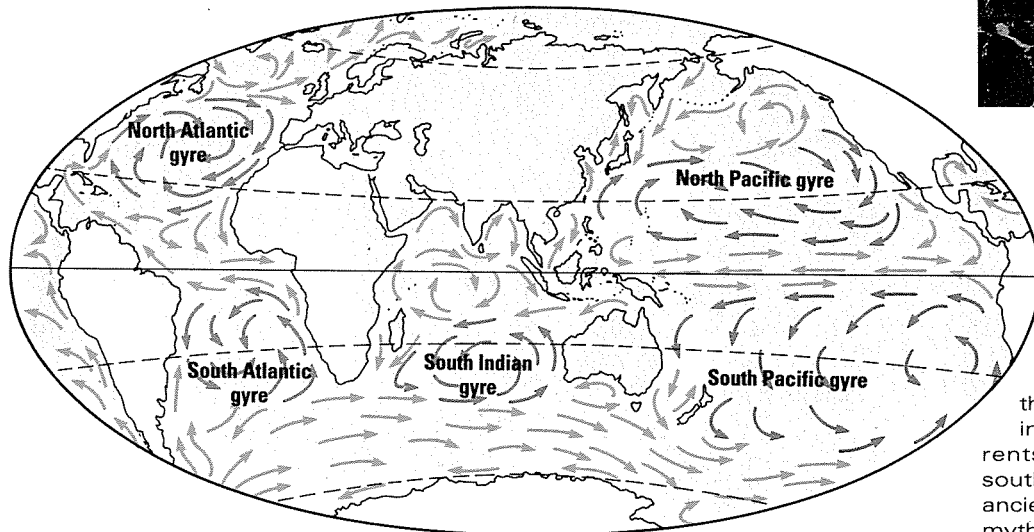
European eels spawn in the Sargasso sea. The young elvers then hitch a ride back to Europe on the Gulf Stream.

A whirlpool forms at the foot of a cliff where the tide surges out through a tunnel at Aber Foel Fawr, Ramsey Island, Wales.

Jane Burton/Bruce Coleman Ltd



Jane Burton/Bruce Coleman Ltd



of Norway. It has been a menace to sailors for hundreds of years. The Maelstrom arises from rocks and tides that oppose the main ocean current and becomes especially dangerous when the wind blows against it between high and low tides.

Another famous whirlpool, the Garofalo, forms because of the interaction of winds and tidal currents along the coast of Calabria in southern Italy. Known to seafarers in ancient times, it is referred to in Greek myth as the monster Charybdis.

RAINING FROGS

Reports are not uncommon of frogs, fish, crabs, and other small animals literally falling out of the sky. For example, in June 1984, the owner of a service station near Thirsk, North Yorkshire – 45 km inland from the British coast – found winkles and starfish covering the forecourt of his garage. The explanation may be that these small creatures were picked up by a whirlwind or waterspout along the east coast of England. Then they were carried aloft for perhaps an hour or more in the powerful updraft of a thunderstorm before dropping back to Earth.

The rotation of the Earth causes five huge circulating masses of water – or gyres – in the oceans. Sailors have taken advantage of these currents for centuries.

deep and 60 km wide. In places it moves at 160 km a day, bringing warm water from the Gulf of Mexico to the shores of western Europe. The Gulf Stream also gives a free ride to millions of baby eels that hatch out in the Sargasso Sea off North America.

In 1947, the Norwegian explorer Thor Heyerdahl showed that South American Indians could have colonized the islands of Polynesia using primitive boats carried along by the South Pacific gyre. Aboard his balsawood raft Kon-Tiki, he and his five-man crew successfully sailed 6,900km from Peru to Tahiti.

The Maelstrom

A large swirling vortex, or whirlpool, is among the most terrifying obstacles to ships at sea. The Maelstrom (Dutch for 'whirling stream'), for instance, is a giant whirlpool that sweeps back and forth between two islands of the Lofoten group off the northwest coast

Thor Heyerdahl rode the South Equatorial Current in his balsawood raft Kon-Tiki, proving South American Indians could have colonized Polynesia.

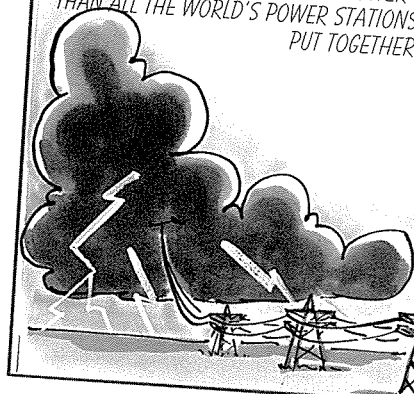
Niagara Falls

Other major whirlpools occur in the strait between Sicily and Italy, in the Naruto Strait connecting the Sea of Japan with the Pacific Ocean and near the Hebrides and Orkneys off the coast of Scotland. Probably the one most visited is Whirlpool Rapids in the gorge below Niagara Falls. This is formed by water circulating round a worn-out basin to the side of the river's main course.

Just amazing!

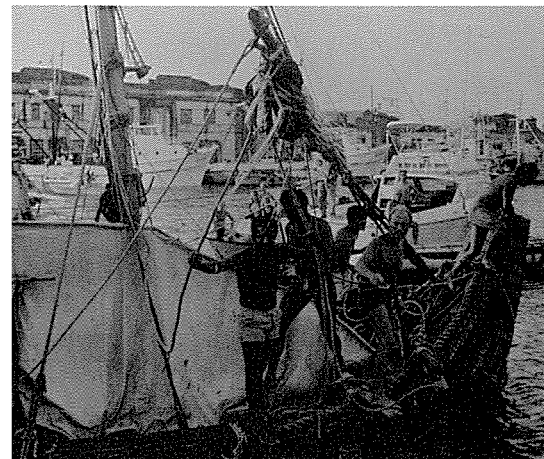
BLOW ME DOWN

A BIG TROPICAL STORM – 1,600 KM ACROSS WITH WINDS UP TO 400 KM/H – CAN GENERATE 100 TIMES MORE POWER THAN ALL THE WORLD'S POWER STATIONS PUT TOGETHER.



Paul Raymond

Rex Features





SITE ORGANIZATION



FOUNDATIONS



PILE-DRIVING

ON SITE

Work in progress on an underground pumping station in England, UK. The site sides, extending deep into the ground, are lined with continuous, concrete, diaphragm walling.

Manual skills are still required on today's building sites, as is a good sense of balance. This worker is painting steel beams with anti-rust paint.

Charles Haswell and Partners

THE BUILDING SITE IS A temporary factory that exists only until a construction project has been completed. And not only buildings are involved – major projects may include roads, bridges, dams, airfields, pipelines and even tunnelling.

First, a site must be examined for its suitability for the proposed building project. The site may have to be drained – if the soil is waterlogged, there is a danger that structures built on it will tilt. It is important to find out what the site was previously used for – possibly tunnelling or the dumping of waste. Waste not only makes the ground liable to sink, but may include harmful chemicals and even generate gases, such as methane. Many sites

are being built on for the second time.

Bore holes are drilled so the subsoil and layers of rock beneath the site can be examined. Decisions can then be made on the depth of foundations, and on whether steel or concrete piles need to be rammed into the

earth as deep foundation supports.

Once the building site has been surveyed, an architect will draw up a set of plans called 'blueprints' that must be followed to the millimetre. The surveyor then uses the blueprints to mark up the site so all boundaries,

Tony Stone Photo Library, London





Construction of a new shopping centre in Basingstoke, near London, UK. The surface of the site has been levelled, and excavated soil and rock transported away.

This bridge at Abu Dhabi in the United Arab Emirates is being put together from units of pre-stressed concrete. High-tensile steel wires inside each slab compress the concrete so it can carry heavy loads without cracking.

Tony Stone Photo Library, London

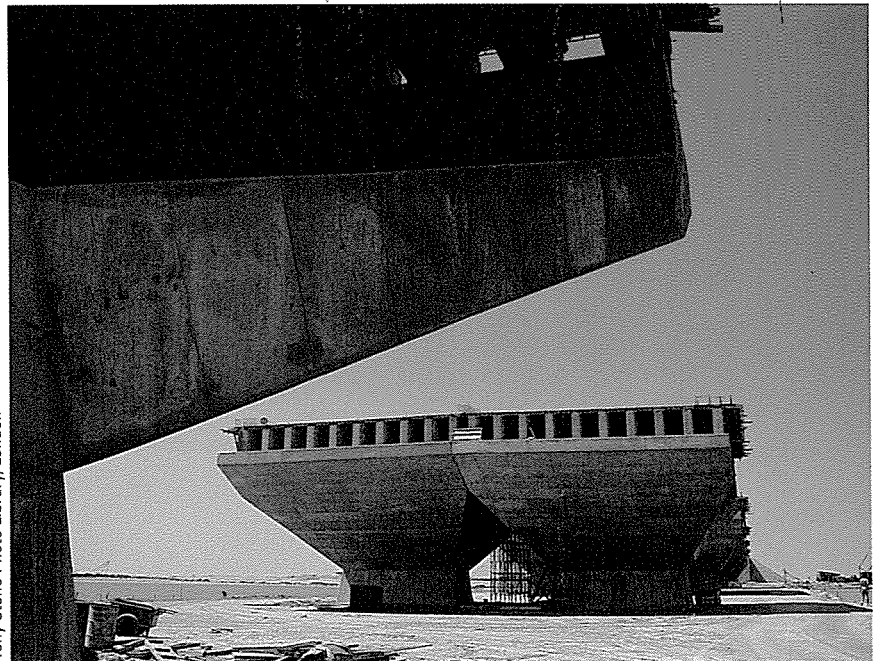
foundations, pipelines and everything else will be exactly in position. It is also the architect's responsibility to detail all the materials to be used and to calculate the stresses and strains that the materials will have to bear. The contractor draws up a 'Master Programme' – a timetable for the project, from beginning to end.

Master plan

Access to the site by road and rail must be considered. In some projects, such as airfields and roadworks, large amounts of earth have to be transported from the site. Areas for stores, spoil heaps and machinery parking are planned. Temporary structures for the building team – storerooms, plant repair shops and supervisors' offices – will all be needed.

Before building begins, the site must be cleared. Any unwanted buildings already on the site are demolished, trees and all plants are pulled up and the top soil is removed

Tony Stone Photo Library, London



SKELETONS OF STEEL

Many multi-storey buildings are constructed around a framework of steel columns and beams that act as load-bearing skeletons. Steel frames are bolted, welded or riveted together. A tower crane or guyed derrick erects the frame. Bolted frames are put together by workmen (as here, on the site of a new sports centre in Sheffield, UK) using spanners or torque wrenches. The bolts are made of high-tensile steel that is stronger than the softer steel in the beams. They can be altered or dismantled more easily than riveted frames, where red-hot rivets are inserted into holes in the steel by special pneumatic or hydraulic tools. Welding has now overtaken riveting in popularity. The region where two pieces of metal touch is heated until the metal melts and the two pieces fuse together. Additional metal may have to be added to produce a good join.



New Builder

in a shape corresponding to the outer and inner walls of the house. A layer of concrete (the strip foundation or footing) at least 250 mm thick is laid at the bottom of the trench, then concrete blocks and sometimes bricks are laid in the trench until they reach a point just below the floor level of the house. 'Floor level' is a 5 cm-thick screed laid over the groundslab.

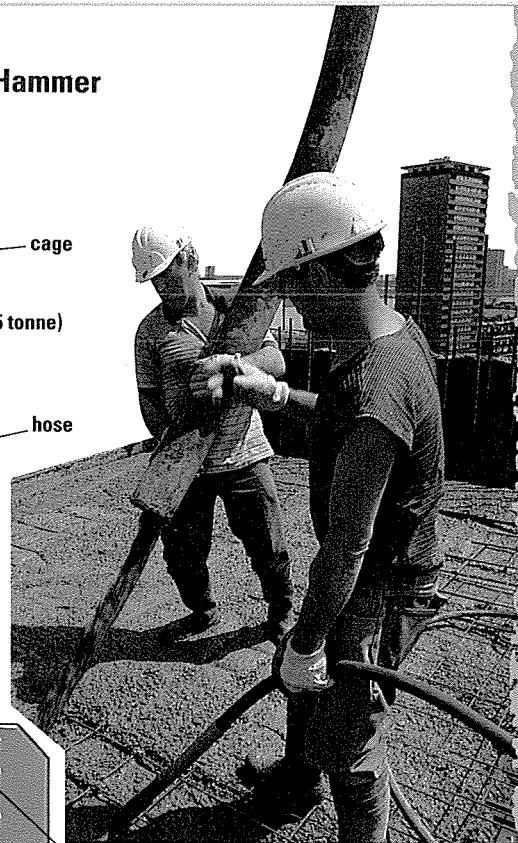
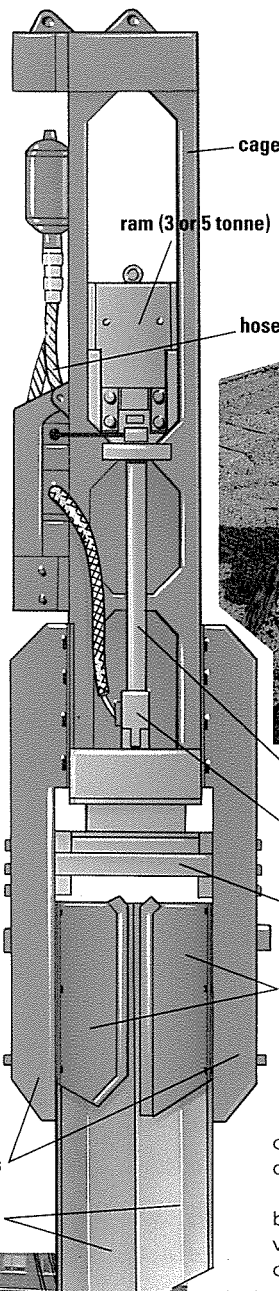
Solid foundations

At this point, the ground area of the house is filled with hardcore (rubble) and covered with a sheet of plastic to keep out damp and a concrete platform called a groundslab or oversite that is levelled off. Concrete is a mixture of cement and aggregate – that is, different-sized grades of rocks or stone. It is usually mixed on site.

In bigger constructions, a mesh of steel may be added to reinforce the concrete. Where a building is on unstable or marshy ground, deep bearing piles (pillars) of concrete or steel may have to be sunk, upon



Hydraulic Drop Hammer



The Builder Group

Wet concrete is poured over a steel mesh to make slabs. Almost all concrete is reinforced with steel rods or wires.

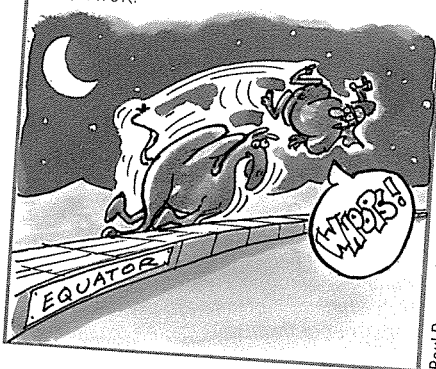
and the inner skin is built of strong, lightweight blocks made from a combination of cement and the residue from coal burned in power stations.

Bricklayers lay the bricks or blocks in interlocking courses with a binding layer of sand and cement. To hold the walls together and give the structure strength, the two skins are held together at intervals by a series of metal ties built into

Just amazing!

EARTH MOVERS

THE EARTH MOVED ON THE WORLD'S BIGGEST SITE, IN SAUDI ARABIA, WOULD BUILD A WALL 7 METRES WIDE AND 1 METRE HIGH AROUND THE EQUATOR.



Paul Raymond

Tony Stone Photo Library, London



Watson and Hillhouse (Plant Hire) Ltd/ Joe Lawrence

To protect this building site (and the workers on it) from the elements, a steel tubular frame has been erected over the site and then draped with flameproof, PVC-reinforced, nylon sheeting.

which the foundations are laid. This will give the building a secure base.

Once the foundations are laid, the main supporting walls are built. For strength and insulation, brick walls are made up of two 'skins' with a gap in between. The outer skin is built of bricks or of concrete blocks that are later coated with sand and cement,

Using a crane, workers position the collar of a buried pile. Behind them, another machine is about to sink a concrete bearing pile into the ground.

A pile-driver drives piles – steel, concrete or timber columns or sheets – into the ground. Sheet piles hold back the sides of pits or trenches. Bearing piles support the weight of a building. The hydraulic-powered drop hammer pushes sheet piles (held in place by inserts) into the ground with a heavy ram.

two steel sheet piles



the brick or blockwork.

When the walls have reached the height of the first storey, carpenters lay out timbers called floor joists that must be strong enough to withstand heavy loads, including internal walls. At this stage too, any metal girders

A bridge, pushed by hydraulic jacks, slides into position. The rate at which the bridge moves is monitored on a television screen.

COVERING UP CONSTRUCTION WORK



When an oil refinery was built at Stanlow in Cheshire, UK, crude oil had to be transported from a buoy off Anglesey, where supertankers unloaded their cargo of oil. A 125 km-long pipeline cut a swath across the countryside of north Wales and north-west England. This is just one example of the damage construction projects can do to the environment – but, in this case, also of how such damage can be remedied. Along much of the pipeline's route the earth, top soil and turf has been put back, returning the land to its former state.



that need to take heavy weights are loaded into position by site-workers or a fork-lift truck or crane.

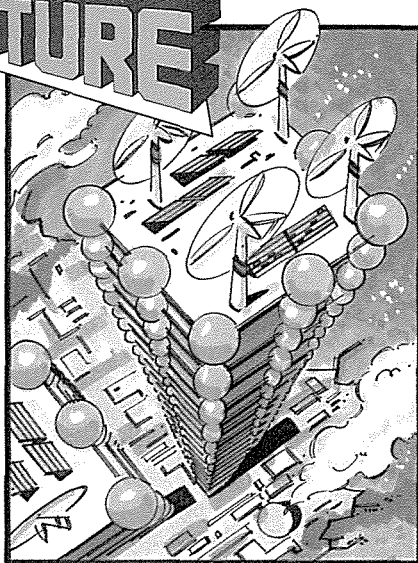
As a building goes up, scaffolding is erected. This is made of a strong tubular steel framework, clipped together and filled with wooden boards to make walkways for the builders.

Off the ground

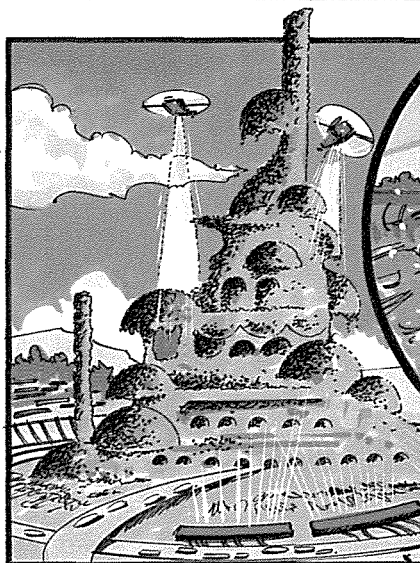
In a house, the skeleton of the roof is usually made from pre-formed timber roof-trusses, held together at the joints with spiked steel plates. This framework is covered successively with a lattice of wooden battens, sheets of bituminous felt and tiles.

Once the roof is on, the internal work can begin. Carpenters, glaziers, plumbers and electricians move in to finish the building.

INTO THE FUTURE



▲ Future building projects will not always make use of today's materials. Housing units stacked high into the sky may be constructed from soya-based plastics.



▲ Buildings at desert oases may be made of a 'hydromulch' of seaweed, cement, plant seeds and water. When watered, the buildings should 'grow'.



▲ 'Trash housing' will incorporate metal, glass and rubber that is currently thrown away as rubbish, and be supplied with solar power and methane gas.

TOMORROW'S MATERIALS





COAST LINES

At Big Sur, an 80-km-long stretch of coast south of Carmel, rocks project above the waves where California's Santa Lucia range of mountains swoops down into the Pacific Ocean.

Hutchinson Library

Seaweeds (marine algae) vary in size from a few centimetres to huge kelps as long as 60 metres.

FORCES OF LAND AND SEA clash daily on coastlines around the world in a mighty, never-ending battle. On some stretches of coast, powerful waves pound relentlessly against rocky cliffs, gradually gnawing them away. But elsewhere the struggle may go the other way, with the land pushing out into the sea.

The presence of rocks or cliffs on the shoreline is a clear sign that the sea is winning. On stormy days, the wind whips up the surface of the sea into large waves that smash against the shore, punching air into the rocks. As the waves retreat, the squashed

air expands, loosening chunks of rock that eventually break away.

Waves also hurl shingle, pebbles and sand against the land, causing further damage. Even plain seawater contains dissolved chemicals that enable it to attack coastal rocks such as chalk and limestone.

Overhanging cliffs

The base of a section of coastline is the first to be eroded. But as the notch deepens, the overhang above grows in size and weight until, in time, it too collapses. In this way, over thousands of years, the most gently sloping coast can be turned into a series of tall, rocky cliffs. The highest cliffs in





Caves on the edge of the Ross Ice Shelf, Antarctica. An ice shelf is a sheet of floating ice attached to a coastline. In time, the ice caves will collapse and large pieces of ice will break off and float free as icebergs.

est slope. As a result, material is moved along the beach in a zig-zag manner known as longshore drift. To help prevent this movement, barriers called groynes are often set up at regular intervals between the high and low tide marks.

Material carried by waves and currents is deposited only when some obstacle slows down the movement of water. Projecting headlands, rivers flowing into the sea, and wind and

Doug Allan/Science Photo Library

the world, on the north coast of Molokai in the Hawaiian Islands, soar vertically for 1,005 metres.

Rocks of different hardness erode at different speeds. In Britain, a stretch of the Yorkshire coast between Flamborough Head and Spurn Point is made of such soft clay that it wears away at a rate of 2 metres a year. Old maps of this region show many towns and villages that have now fallen into the sea.

Bays and coves

Since softer rocks are eroded faster, they give rise to bays separated by peninsulas of harder rock. In some places, the sea may make a small opening in a ridge of hard rock, then eat away the softer rock behind to form a cove. Such places make ideal

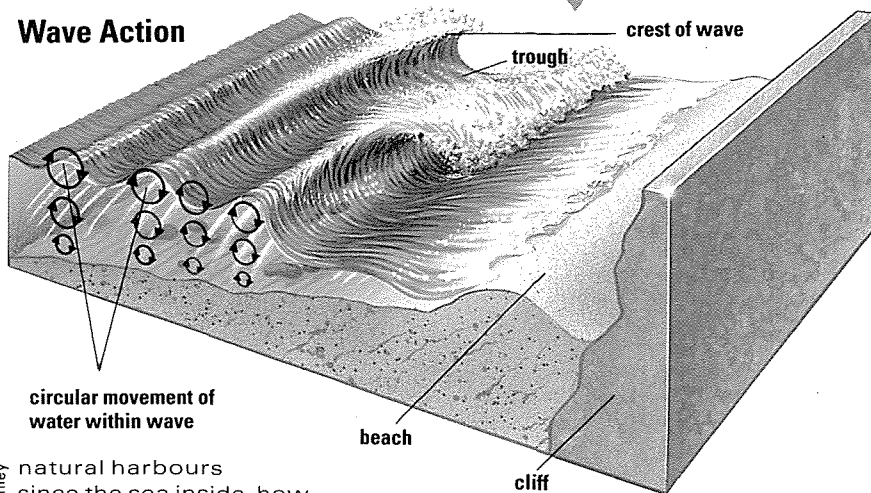
Black sand beach, Kalapana, Hawaii. The beach is black because it is made up of fragments of lava from Hawaii's volcanoes.

Each wave is pushed forward by the wind and down by gravity. Particles of water move up, forwards and downwards with the crest of a wave, then backwards and upwards with the trough that follows.

Tony Waltham



Wave Action



Simon Critchley

natural harbours since the sea inside, however rough outside, is always calm.

Any cracks or joints in cliff rocks are worn away faster than the rest of the cliff-face. The waves slam into these gaps and gradually widen them to make caves. As the water dashes against weak points in the cave roof, it may wear a hole right through. At high tide waves surge up this passage, known as a blowhole, and seawater sprays out like a geyser.

If caves form back to back on both sides of a headland, eventually they may meet to make an arch. Later, when the roof of the arch falls in, a pillar of rock called a stack is left, separated from the mainland by a nar-

row channel of sea.

The debris produced by coastal erosion is transported away from where it falls by waves and currents. Heavy rocks and pebbles are rolled along the sea bed, slowly being ground down into smaller particles, which are carried suspended in the water. All the time, the debris is sorted according to size so that there is a gradual progression from large boulders at the base of cliffs to fine sand further down the beach.

Typically, the wind drives waves up a beach at an angle. The waves then return directly down the steep-

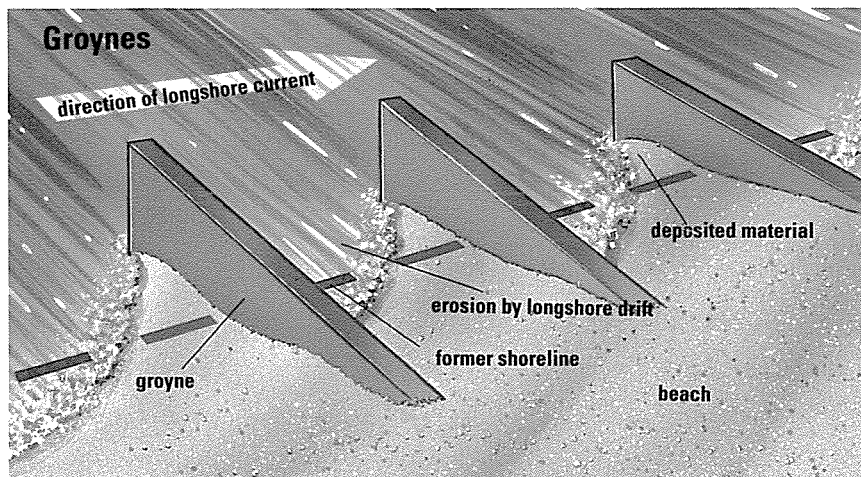
SEA TURTLES



Every two or three years, female sea turtles return to the beach where they were themselves hatched, to lay their eggs. The turtles often arrive in large groups, sometimes covering a stretch of shore in a 'carpet' of turtles. Each female (such as the giant leatherback turtle, above) digs a hole in the sand with her back legs and then lays as many as 200 eggs. Having covered the eggs with sand and firmly packed it down, the female returns to the sea. Between two and three months later, the eggs hatch and the baby turtles make their perilous dash for the sea. Picked off by predators such as seabirds, crabs, and humans, only one or two turtles from a nest may survive.

Jany Sauvane/NHPA





tween high and low tide must be able to survive both underwater and exposed to air. They also have to endure the battering of waves and drastic changes of temperature, as rockpools are warmed by the Sun and then cool down rapidly at night.

Shore life

Some seashore animals, like the limpet, mussel and barnacle, have tough shells and special organs that allow them to cling on firmly to rocks at low tide. Others, such as cockles, razor shells, and lugworms, bury into moist sand or mud for protection.

Seaweeds, too, are specially adapted to a life of saltwater and air. Unlike land plants, they have no stems,

currents moving against the main flow, all have the effect of causing seawater to drop its load.

Beaches are the most obvious feature of deposition. These tend to be widest along lowland coasts and narrowest at the foot of steep cliffs.

On the beach

The colour and coarseness of beaches depend on their source. The black sand on Hawaiian beaches, for example, comes from the lava spewed out of the volcanoes of these islands. Some beaches in the Bermuda group, on the other hand, are pale pink because their sand is stained by a type of red plankton.

On gently sloping shores, bars are a common sight. These ridges of sand or shingle, running parallel to the

Barriers jutting out into the sea, called groyne, are erected between high and low tide marks to stabilize a beach that is being shifted or destroyed by longshore currents. These carry sand and shingle along the length of the beach.



Hurricane Carol lashes into North America's east coast, as part of the erosion process that is causing the coastline to retreat. At Cape Hatteras, North Carolina, USA, for example, the shoreline has moved back more than 426 metres in 110 years.

A sea stack emerges when surrounding softer rock is eroded away. James Bond Island, here, is close to Phuket off the west coast of Thailand. Part of The Man with a Golden Gun was filmed here.

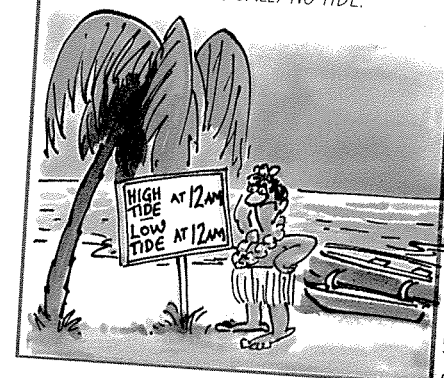
leaves, or roots. Instead, they absorb the nutrients they need directly through their body walls. They also have no means of support so that when exposed at low tide they hang limply over the rocks. Some seaweeds anchor themselves to the seabed by means of rootlike parts called holdfasts, while others float freely in the water on pockets of air.

Dan Farber/Science Photo Library

Just amazing!

HIGH TIDE

THE WORLD'S BIGGEST MEAN SPRING TIDE RANGE - 14.5 METRES - IS AT BURNCOAT HEAD, NOVA SCOTIA, CANADA. TAHITI, BY CONTRAST, HAS VIRTUALLY NO TIDE.



Paul Raymond

coast, form when waves stir up loose material from the seabed. If the waves then break before they reach shore, the suspended particles in them fall and build up, first as a submarine bar, then as a strip of land above sea level.

The famous beach at Miami, Florida, is an offshore bar with a lagoon

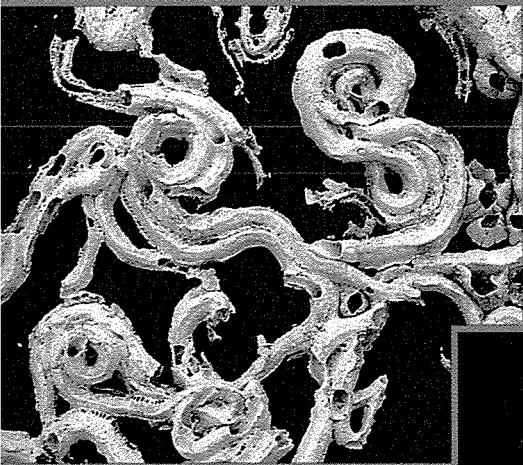
behind it. Bars are also found at the mouths of estuaries, when a river drops a lot of sand or mud before flowing into the sea.

The margin of sea and land is a challenging environment for the animals and plants that have to live there. Creatures inhabiting the zone be-





VIEW IN THE SHALLOWS



Many bristle worms live in tubes built from sand, mucus or carbonate of lime. The worm emerges from its tube to look for food, trapping water-borne particles of animal or vegetable matter in its bristles.

JH Carmichael/NHPA



The bright colouring of this sea slug warns predators that it will secrete toxic substances when threatened.

Starfish feeding on mussels. The starfish's stomach, extruded through its mouth, covers and then digests the unfortunate mussel.

R Waller/NHPA

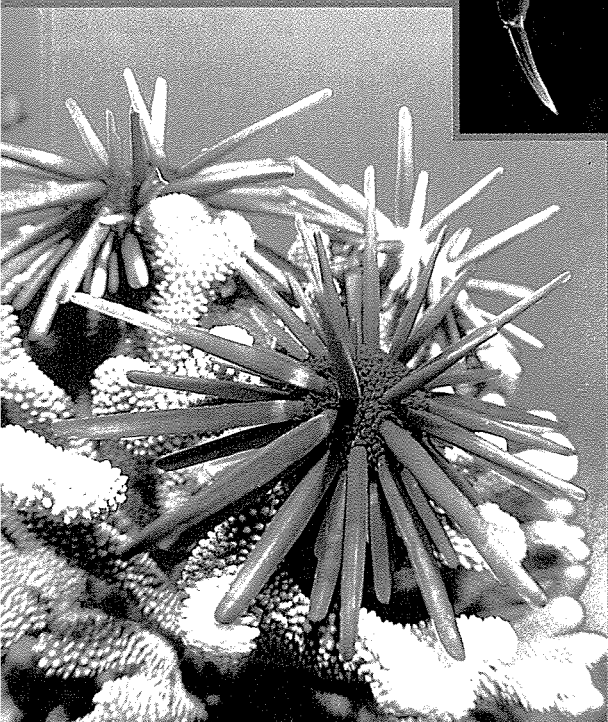


A female shore crab, with a mass of orange-coloured eggs attached to her abdomen. She carries the eggs for 12-18 weeks before they hatch into tiny transparent larvae.

Sea urchins have a rigid internal shell out of which emerge spines and tiny claws. 'Tube-feet', used for walking and feeding, protrude from the sides of the shell.

L Campbell/NHPA

H Voigtman/Planet Earth Pictures



J Burton/Bruce Coleman Ltd



Oarweed is one kind of kelp, a large brown seaweed. It grows off most European coasts, below the low-water mark. These primitive plants, which can grow up to 3 metres long, are edible and are also used as fertilizer.

J Foot/Bruce Coleman Ltd



G Dowman/Planet Earth Pictures

The giant green sea anemone paralyses a small fish or animal with stinging cells on its tentacles and then pushes the catch, whole, into its sac-like body.



WATERS

A DESOLATE BODY OF WATER and ice where temperatures rarely rise above 8° C, the Arctic Ocean, which dominates the north polar region, is a bleak and hostile environment.

Both the north and south polar regions are wildernesses of ice caps, snowstorms, and biting winds. But whereas the Antarctic has beneath its layer of ice a great continent twice the size of Australia, the Arctic is an ocean, at the north of the planet, nearly 5,300 km across, which is almost completely encircled by land.

During the summer, only the central part of the Arctic is frozen. This includes the permanent pack ice around the North Pole that never melts. But, as the winter approaches, the ice cover begins to spread southwards and the entire ocean becomes locked by ice as temperatures plunge down as low as -70° C.

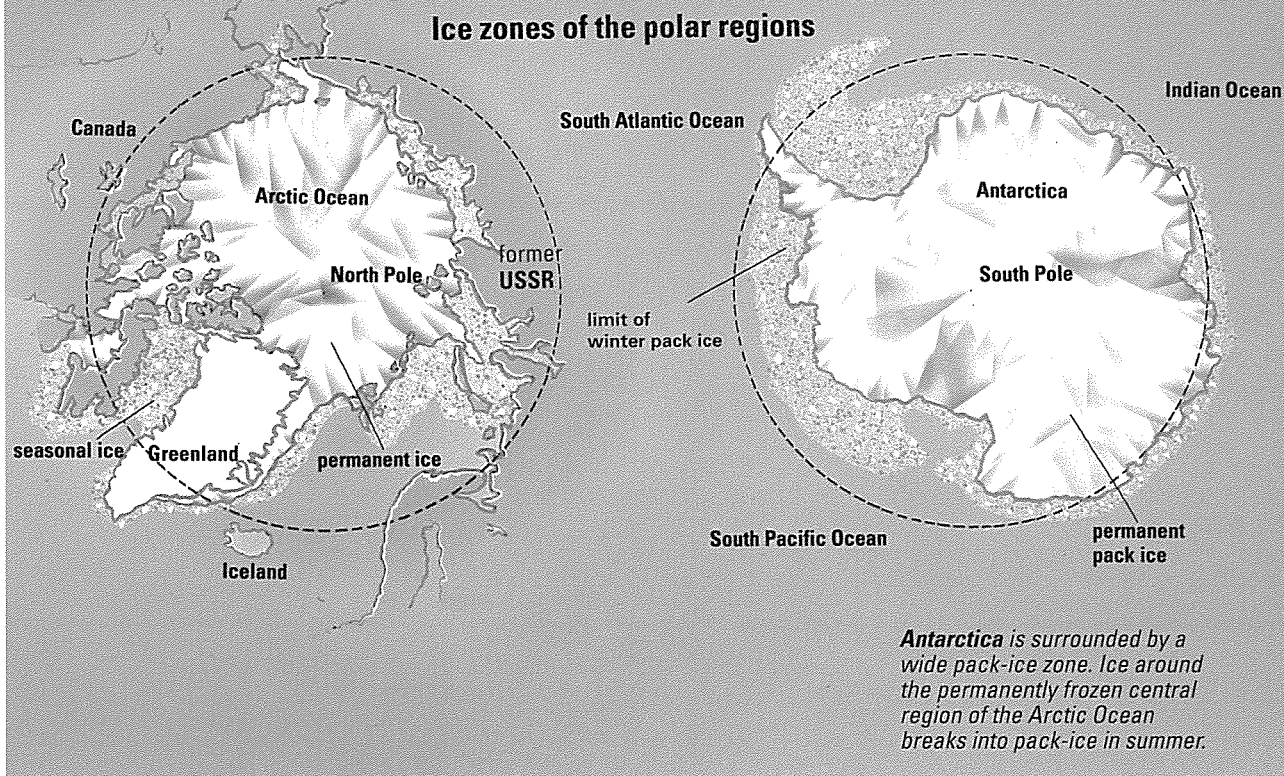
Because of the dissolved substances in it, seawater must be colder than pure water to freeze. Instead of freezing at 0° C, the temperature of seawater has to drop to about -2° C before it starts to turn to ice. When

Sure-footed huskies and other sled-pulling dogs provide efficient transport across the polar regions.

Derek Fordham/Arctic Camera

Jen & Des Barlett/Bruce Coleman Ltd



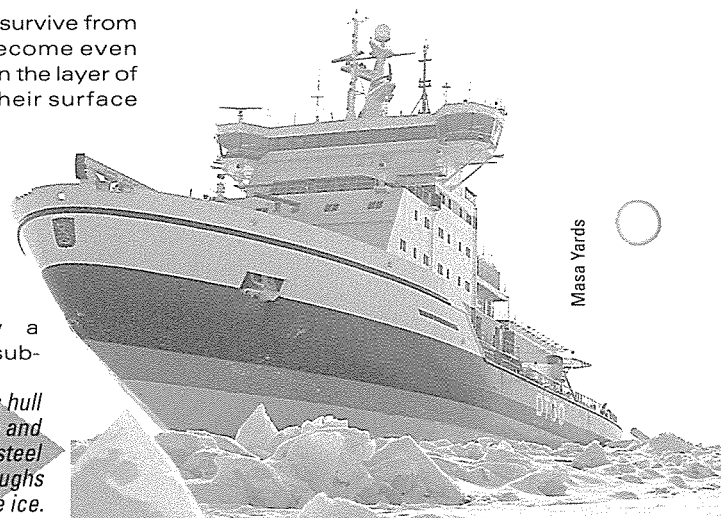


this happens, the dissolved substances drop from the ice to the unfrozen water below. Sea ice, therefore, is made of pure water.

The build-up of ice on the ocean surface takes place in several stages. First, small crystals of ice form and join together forming thin platelets called pancake ice. These pancakes freeze together to create an ice shelf or floe about two to three metres

thick. Any ice sheets that survive from the previous summer become even thicker and stronger when the layer of melted ice that lies on their surface freezes over again in the winter months.

Being lighter than water, sea ice floats, insulating the water below from the bitterly cold air. This means that the Arctic Ocean is always clear below a certain depth, allowing sub-



FLOATING ICE



One of the most spectacular sights in polar seas, icebergs are huge chunks of ice that have broken away from glaciers – slow-moving rivers of ice, which flow down the sides of mountains in Antarctica and the lands encircling the Arctic Ocean. About 12,000 icebergs are produced by glaciers in Greenland each year. Driven by winds and currents from the Arctic into the North Atlantic, many become a hazard to shipping. Large glaciers are tracked by the International Ice Patrol and towed away if they move into shipping lanes. This organization was formed in 1913, a year after the giant liner *Titanic* struck a small iceberg and sank on its maiden voyage.

An ice breaker, with its hull designed for low resistance and surrounded by a stainless steel compound shell-plate, ploughs its way through the ice.



The skidoo's low ground pressure prevents it from sinking into snow or ice. Capable of towing loads of up to 500 kg, it has a small ski at the front and two at the back for steering, while a caterpillar track drives it forward.

marines to pass directly under the North Pole even in winter.

To generations of explorers who have tried to reach the North Pole, the Arctic has presented one of the most formidable obstacle courses on Earth. Blizzards lasting for days, temperatures so low that exposed skin can freeze in seconds and shifting ice underfoot are just some of the hazards they have had to face.

Most overland polar expeditions set out from the northern coast of Ellesmere Island, Canada, at around latitude 83°N. The straight-line distance from here to the North Pole is 769 km, all of which can be covered on foot or dog sled during the frozen winter and spring months.

Unfortunately, the ice is not all smooth and unbroken. Wind and undersea currents cause the ice to shear

Just amazing!

DEEP FREEZER

DURING A 1986 ARCTIC EXPEDITION ANN BANCROFT FELL INTO THE OCEAN. HAVING CHANGED CLOTHES AT -30°C, SHE TOOK TWO DAYS TO WARM UP.



Paul Raymond

Phytoplankton – a mass of tiny plants that drift or float passively in Arctic waters – are a vital part of the marine food chain.

Today, Inuit live in wooden houses and usually travel about in pick-up trucks or motorized sledges called snowmobiles. However, they have recently been granted large areas of land of their own and now combine an up-to-date lifestyle with their own hunting traditions, culture and language.

A wide variety of animals and plants thrive in and around the Arctic waters. In summer, the Sun's rays shine almost 24 hours a day on the Arctic, stimulating the growth of trillions of microscopic plants called phytoplankton. These form the basis of a marine food chain. Animals such

A false-colour satellite image of the Arctic Ocean in the summer months shows the various densities of phytoplankton in the surface water.

and buckle. This gives rise to areas of open water known as leads and, in other places, a maze of ice rubble called a pressure ridge where two ice shelves have rammed into one another. Crossing a lead or pressure ridge is dangerous, time-consuming and extremely exhausting.

Frostbite

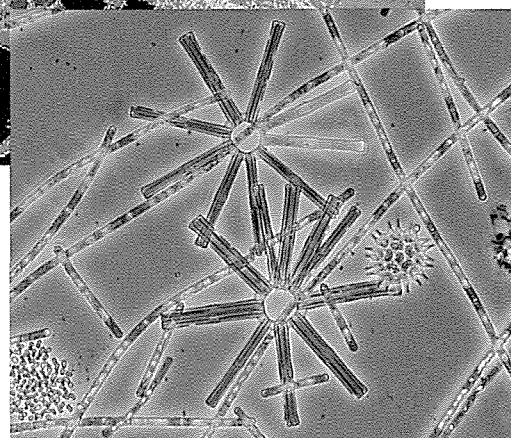
Temperatures of -30°C or lower pose a constant threat of frostbite and the slightest wind can cause eyelids to freeze shut. Highly insulated, layered clothing is essential, but even this becomes soaked with several kilos of sweat during a polar trek and cannot prevent at least some frostbite to the face, fingers and toes.

One of the main enemies of all polar expeditions is time. A team of men and dogs can only haul so much food and other supplies on their sleds.

VOYAGE UNDER ICE

The first nuclear-powered submarine to be built, the *USS Nautilus*, was also the first submarine to travel under the North Pole, in 1958. Its onboard reactor allowed it to remain under the water for several months at a time, dive as deep as 400 metres, and travel at 40 km/h. After leaving Hawaii on its historic journey, with Commander Anderson in charge, the *Nautilus* headed towards the UK by way of the Arctic Ocean. It passed directly under the North Pole at 11.15 a.m. on 3 August, 1958.

Frieder Sauer/Bruce Coleman Ltd



If bad weather and treacherous ice conditions delay the team by more than a few days, then the expedition may have to be abandoned.

One group of people that have fully adapted to life in the Arctic are the Eskimos, or Inuit as they are properly

A student team makes preparations to establish a base camp at Eureka on the Arctic Circle for the Icewalk – an eight-man expedition team to the North Pole. The aim of the expedition was to involve young people in the Icewalk call for action concerning pollution, in particular the holes in the ozone layer.

Rex Features



called. Most Inuit live north of the Arctic Circle in Greenland, Alaska, and on the northern coast of Canada. Until recently, they used cut blocks of ice to build igloos, which they heated with seal-oil lamps. They also trained dogs to pull sledges called komatiks and hunted seals, walrus, and caribou with spears and harpoons.

as shrimp-like krill feed on the phytoplankton and they in turn are eaten by larger creatures such as whales, seals, fish, and seabirds.

Thick layers of fat, feathers or fur help to insulate Arctic animals from the chilly air and sea. Walrus, for instance, have blubber that is up to 15 cm thick in places and can weigh



well over 400 kg by itself. An adult male may weigh up to 1,600 kg – the same as 23 fully grown men – and sport tusks one metre long. Walrus use their tusks for fighting, hauling themselves along the ice and stirring up mud on the bottom of the sea in search of the shellfish they like to eat.



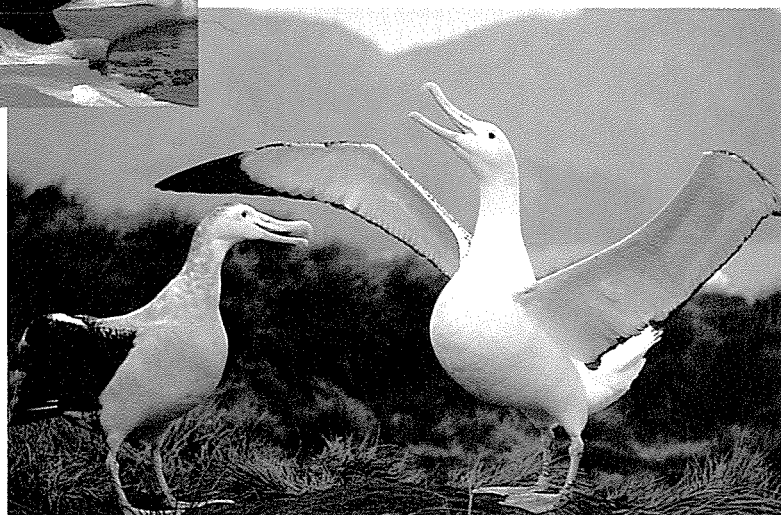
A walrus's teeth are made for a diet of molluscs. Huge canines in the upper jaw are used for digging the molluscs from the ground or scraping them off rocks. The walrus removes the shell and eats the soft parts.

largest and strongest. A fully grown male may weigh up to 450 kg and measure 2.7 m in length.

Polar bears will eat almost anything, including fish, birds and their eggs, and scraps thrown out by people. One of the few tourist attractions in the little, isolated community of

Seals and young walrus are one of the favourite meals of killer whales. Sometimes two or more killer whales will work together to capture a seal that is resting on an ice floe. One whale pushes up the side of the floe while another waits with its jaws open wide to catch the seal as it slides off.

Of the land animals inhabiting the Arctic, the polar bear is by far the



Albatrosses during their elaborate mating ritual on special breeding islands squeal and clash their beaks together.

Churchill on Hudson Bay is the annual visit of polar bears to the town's rubbish tip. On the open ice, however, polar bears prefer seals which they stun with a swipe of their front paws and then tear apart with their teeth and claws.

Seals can move about on land, but their powerful hind flippers and front steering flippers allow them to move faster and more gracefully in water.

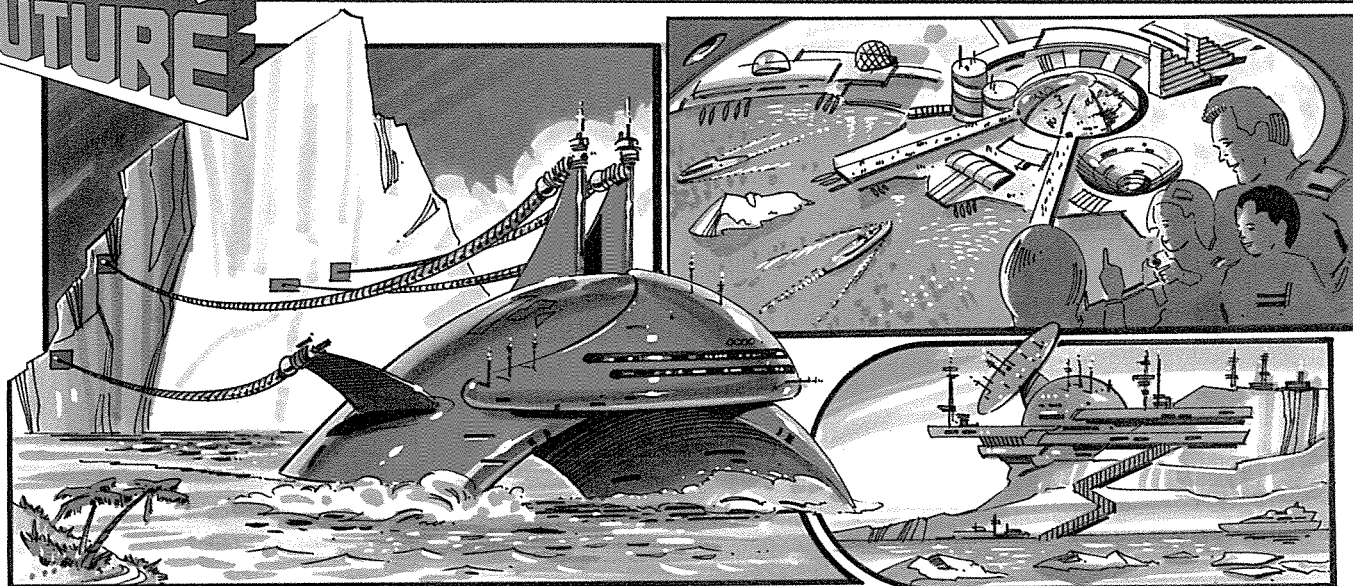
Polar bears

To get from one floe to another, polar bears dive in and swim, paddling with their front legs and using their hind legs as a steering rudder. They can remain in the near-frozen sea for several hours. Their thick, oily fur and a layer of fat ensure that they stay warm.



INTO THE FUTURE

NEW POLAR HORIZONS



▲ In the next century, icebergs might be towed thousands of kilometres to dry regions where they would be melted down to supply pure water.

▲ The Arctic and Antarctic could become booming tourist destinations with hotels located on or below the ice and cruises to see icebergs and marine life.

▲ Large scientific stations will be set up in the polar regions to study the vanishing ozone layer and other effects humans have had on the environment.

Q NEW MATERIALS Q LARGE BREAKS
Q FIRE DAMAGE

FACE-LIFT

RESTORING A PRICELESS work of art to its original condition calls for more than just immense skill and patience. It involves using the latest developments in high technology, computers and chemical treatments.

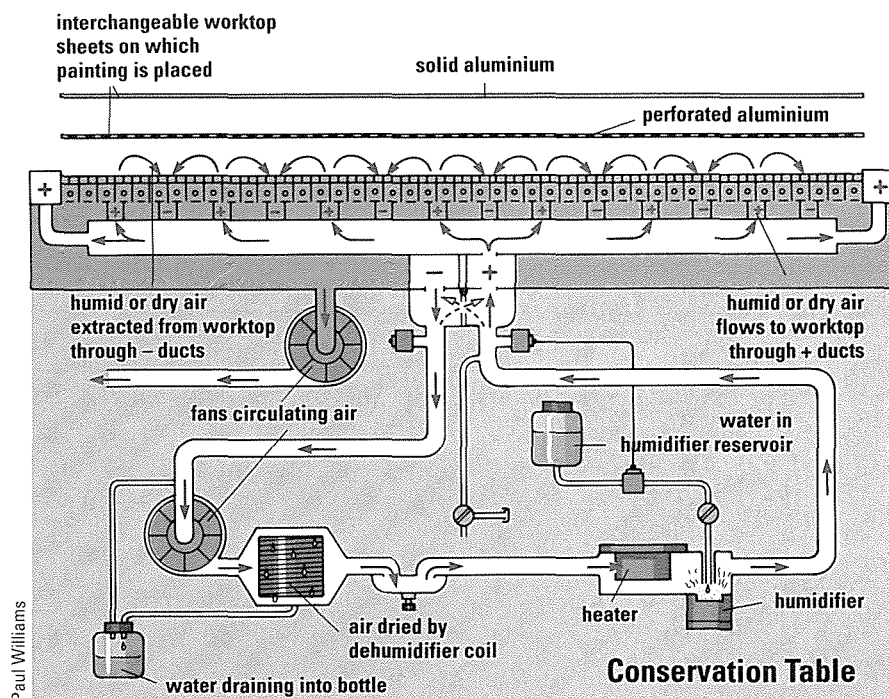
First, the restorer seeks to avoid any further damage or deterioration to the artwork, whether it be a painting, a stained glass window, a sculpture, or an entire building. In the next stage, detailed photographs are taken of the object and a thorough analysis carried out of its current state and make-up. Finally, the restorer has to decide what methods to use in the restoration process and then painstakingly apply them.

One of the most remarkable and famous series of paintings in the world

Restorers working on over 500 square metres of wall paintings in the tomb of Nefertari, a Queen of Ancient Egypt. A top priority is refixing the painted plaster to the walls with special adhesives.

Ultra violet light (right) is used to analyze the structure of the painted surfaces.





With warm, humid air circulating around a painting, restorers can apply and remove glue on the canvas back and repair cracking in the paint, before the painting is dried.

work. A sponge was dipped in distilled or de-ionized water and gently wiped over a small section of the fresco. With a natural-bristle brush, a cleaning solution, known as AB57, was then applied. AB57 is made of

Rex Features Ltd



The statue of Christ overlooking Rio de Janeiro, Brazil, had to be repaired, after the 30-metre-tall statue's soapstone cladding began to crack.

bicarbonates of sodium and ammonium together with an antibacterial, antifungal agent, mixed in carboxymethylcellulose and water. The result is a gel that, within about three minutes, dissolves the grime and can

is on the ceiling of the Vatican's Sistine Chapel in Rome, Italy. They were painted by Michelangelo between 1508 and 1512. He painted directly on to wet plaster in a technique called *fresco*, meaning fresh.

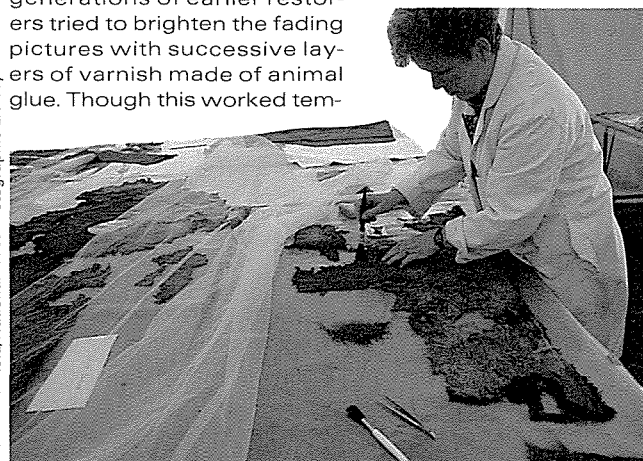
Masterpiece revealed

Unfortunately, more than 450 years of Rome's dust, together with sooty grease from burning candle tallow, dulled the masterpiece. Worst of all, generations of earlier restorers tried to brighten the fading pictures with successive layers of varnish made of animal glue. Though this worked tem-

Minute samples were also taken of the pigment itself. These samples were suspended in a polyester resin, allowed to harden, and cut into cross-sections. Examination under a microscope then revealed the order in which foreign matter, such as later varnish and dirt, was deposited on top of the original painting.

Armed with this knowledge, the restorers began to remove the centuries of grime that coated Michelangelo's

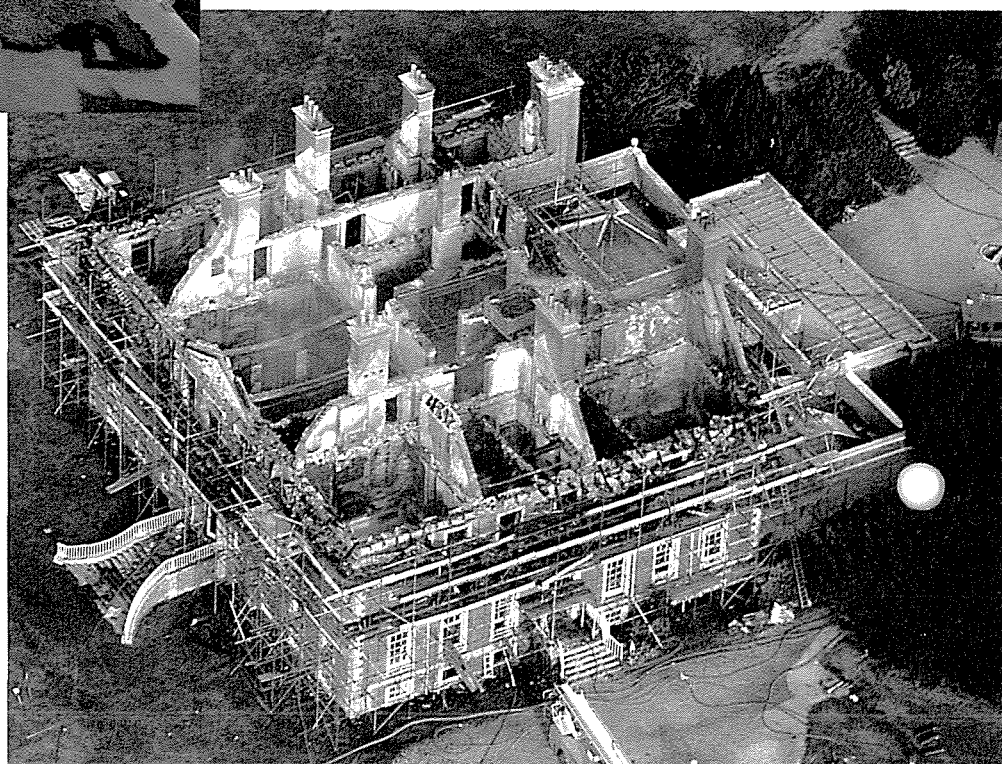
Uppark House in southern England was nearly burned to the ground in 1989. As part of the rebuilding programme, some 750,000 fragments of plaster, wood, metal and textiles (left) were recovered and re-used.



porarily, in the long run each layer of varnish darkened, giving the ceiling paintings an even more dingy appearance than before. As a result, the Vatican decided recently to employ a team of Italian experts to restore the Sistine Chapel ceiling using the most up-to-date methods available.

Before any actual cleaning began, a battery of tests was carried out to reveal the history of the frescoes over the centuries. The main object was to distinguish the original work from that added by later artists and restorers. Infrared light was used to penetrate old varnish and overpainting to show Michelangelo's original fine details. Taken in ultraviolet light, on the other hand, photographs were able to highlight additions and changes.

The News, Portsmouth



© Nippon Television Network Corporation 1990



be removed with sponge and water.

Other restoration work in the Sistine Chapel is concerned with replacing plaster that is loose or has fallen off. During the 18th century, T-shaped bronze clamps were inserted to anchor weaker sections of plaster. Where these cause no problem, they are left as part of the ceiling's history. When clamps are removed, thin pieces of gauze are pasted on to the areas that must be preserved while the background plaster is being delicately chiselled away and replaced.

God's hand in Michelangelo's painting in the Sistine Chapel was repainted 400 years ago. Recently, surrounding plaster was replaced but the hand was kept.



Philip Bier/Sunday Times, London

Data programming

At every stage, a computer is used to record the progress of the restoration. All the results of the photographic survey and laboratory analyses, together with the exact position of cracks, metal clamps, weak areas of plaster, and restored parts can be viewed on a colour graphic display.

When part of a painting or fresco is missing, the restorer can leave the painting as it is, or copy the original artist's style and colour (the usual



A replica of a painting, one of nine, being moved into position at the Queen's House, Greenwich, London, UK. The original paintings (now elsewhere) were photographed and copies printed out at full size. To fill gaps in the copies, a computer (left) duplicated images from the paintings and 'pasted' them into blank areas.

historic house to its original state.

Four thousand labelled plastic dustbins of debris were sieved for fragments of metal, wood and plaster, which were all tagged, and catalogued on computer disc. These have been used in a rebuilding operation that will go on into the next century.

Plasterwork

One of the finest features of the interior was the plasterwork. Though a few large ceiling sections survived, most of the plaster was in thousands of tiny pieces. These were stored in labelled trays in humidity-controlled sheds (called terrapins) and were reassembled in a huge purpose-built

practice when restoring oil paintings) or paint in the lost area in such a way that it is clearly not part of the original. With fresco restorers, the last option is the most popular.

Some of the best surviving ancient Egyptian frescoes were discovered in the 3,200-year-old tomb of Nefertari, Queen of one of the most famous Pharaohs of Ancient Egypt, Rameses II. But they have deteriorated to the point where portions of plaster have fallen off the rock wall, spoiling the appearance of the paintings.

A team of restorers is now reattaching the painted plaster to the wall and using a technique called *trategio* to replace the lost artwork. The

Just amazing!

OPENING A NEW DOOR

MONKS IN A MONASTERY OUTSIDE MILAN, ITALY, BUILT A NEW DOORWAY INTO THEIR DINING HALL, UNDETERRED THAT IT WENT THROUGH THE MIDDLE OF LEONARDO DA VINCI'S MASTERPIECE 'THE LAST SUPPER'.



Paul Raymond





The Great Palace in Pushkin (formerly Tsarskoye Selo) outside Leningrad in the USSR was looted and partially destroyed during World War II. It has since been restored and is now a museum.

DAMAGED FURNITURE

Rough handling is not the only way in which old furniture can be damaged. Woodworm is one problem: the best treatment is methyl bromide gas, since liquid pesticides can easily ruin lacquered or gilded surfaces. Another major cause of damage is central heating, which reduces the level of moisture in the air. In the past, European furniture was built from timber seasoned so it would last well in a damp, cool climate. Central heating dries out the wood, splitting it and causing veneers to peel. However, humidifiers and air conditioning will keep the atmosphere moist and the temperature down.

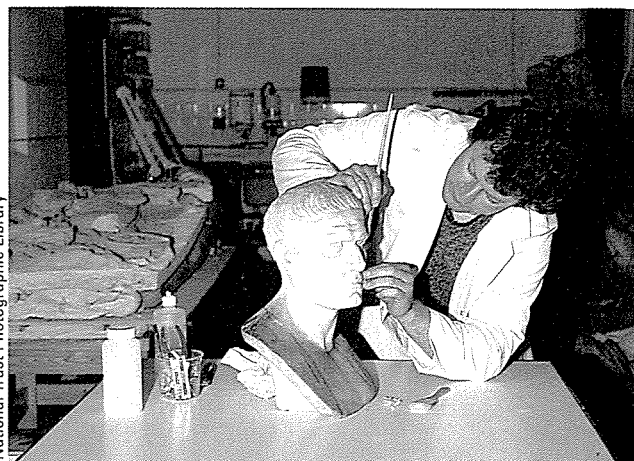
hanger.

Small pieces of sculpture or pottery can be glued back together using a very strong polyester resin. Chips are often replaced with solid polyvinyl acetate, which is easily moulded and can be coloured. For larger breaks in a sculpture, such as when a life-size arm is broken in two, dowelling is usually the best answer.

Sculpture

A spot of coloured paint is put on the centre of one half, and the two pieces fitted together. In this way the corresponding point on the other half is marked. Next, a hole about 8 cm deep and 1 cm wide is bored through the centre of each mark. Great care must be taken that the holes are aligned properly. Finally, a stainless-steel dowel is inserted and the two halves are stuck together with adhesive.

Although restoration techniques



This stone bust is being cleaned and repaired by a sculpture conservator. He is gluing chips back into place, over the statue's left eye. The bust is in two parts, which are held together with a dowel (probably made of iron).

have come a long way, researchers are still looking for new substances that will last longer and give better results. For example, a new varnish is needed to help protect paintings. Natural resin varnishes, used in the past,

begin to deteriorate only 10 years or so after they are applied. The most stable varnish in use today is a synthetic acrylic one, Paraloid B72. It may be more durable, but it fails to match the quality of natural resin varnishes.

INTO THE FUTURE

COMPUTER MASTERCLASS



▲ By analysing the composition of paint, the brush strokes and the sequence of painting, restorers can work out exactly how a masterpiece was created.

▲ After feeding this information into a computer, it would be possible to teach a computer to paint a picture in the style of Leonardo da Vinci, Goya or Rembrandt.

▲ Then, damaged masterpieces could be restored by having the computer paint in the missing section – or even create a new masterpiece of its own.



SMOG



ACID RAIN



OZONE

IN FILMS, VICTORIAN

London is always depicted shrouded in fog as thick as pea soup. This was 'smog' caused by all the wood and coal burning in the city that disappeared when open fires were outlawed. Yet even though the 'peasoupers' have gone, the air in most cities is still hazardous both to people and to the environment.

In Athens and Los Angeles, it is easy to see the thin smog that hangs over the city. But most of the harmful gases are invisible and have no smell. They come from factories, coal-fired power stations and cars.



Danger gases

In humans, these gases can lead to the development of asthma, bronchitis and brain disease. They are also linked to the wider problems of acid rain, the greenhouse effect and the thinning of the ozone layer.

One of the most dangerous gases polluting our cities is carbon monoxide, the largest source being road vehicles. When inhaled, molecules of carbon monoxide attach themselves to the red blood cells.



Damage and death

They form compounds which prevent the cells from carrying oxygen around the body and effectively kill off the red cells. If too little oxygen reaches the

Smoke from the chimneys of coal-fired power stations is one of the main causes of air pollution.

SOOTY AIR





limestone and granite that were used to build our ancient cities.

The acid can also be carried a long way in the clouds. The output of British power stations causes acid rain in Scandinavia where the soil has a natural acidity. In southern Norway, 33,000 sq km of lakes have been affected – some 13,000 sq km have no fish life left at all.

'Lichen deserts'

Trout and salmon have been particularly affected, along with mammals that feed on them. Insects and trees have also been badly affected by acid rain. Many forests in northern and central Europe have been killed. The acid attacks their needles. In the early 1990s almost half of Britain was getting more acid fallout than it could cope with. Lichen are particularly vulnerable. Air pollution has caused many 'lichen deserts'.

Most fuels – like petrol or coal – are hydrocarbons, compounds made up

brain, reflexes and thinking slow down, and even death may result. Those most at risk are people with heart problems, young children and the elderly.

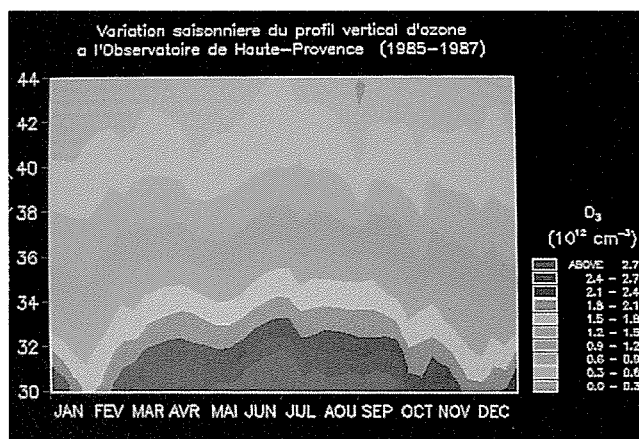
Breathing problems

Most nitrous oxides also come from cars, although power stations are another source. These oxides cause breathing problems. They can aggravate bronchitis and chest infections and can cause acute difficulties for asthma sufferers.

High levels of sulphur dioxide can cause restrictions of the bronchi – these are the tiny tubes that carry air

In Los Angeles, USA, only the tallest buildings are able to stick out above the low-lying smog.

A computer graph of the atmosphere above Haute-Provence in France shows the varying levels of ozone at different altitudes. The highest concentration is at the lowest altitude.



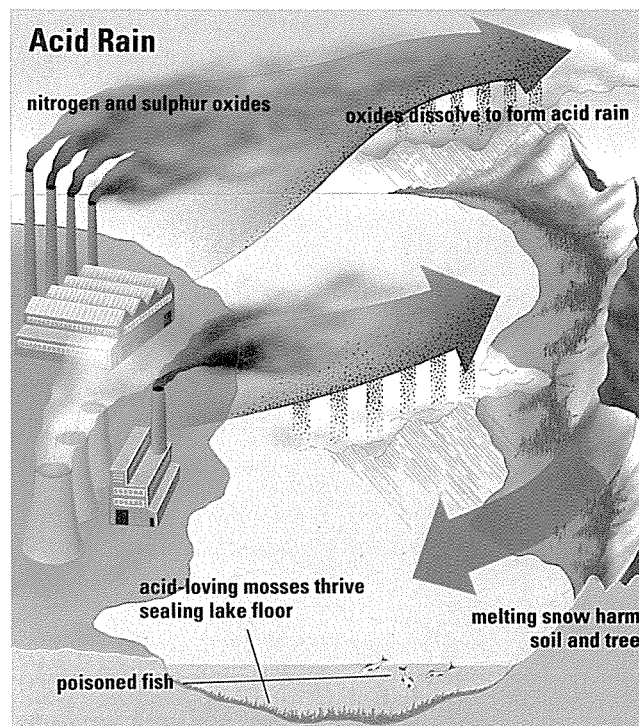
A scientist measures acid rain pollution in a conifer forest. Affected trees are stunted, with yellowing and dropping needles.

of carbon and hydrogen. When they are burnt, they turn into water and carbon dioxide. But if the burning is not complete, hydrocarbons are emitted along with the exhaust gases out of, say, the chimney of a power station or the exhaust of a car. These hydrocarbons form the fine, invisible

in the lungs. This is particularly dangerous to asthmatics (sulphur dioxide was the cause of most of the deaths during the London fogs). Sulphur dioxide is produced by coal-fired power stations, paper mills, mining and smelting operations, and domestic fires.

Both nitrous oxides and sulphur dioxide have other effects, too. They make acid when dissolved in water and are the major causes of acid rain. Acid rain eats away at the marble,

Acid rain is caused by gases from power stations and cars mixing with water vapour in the air. The acidity or alkalinity of rain is measured in pH figures. Normal rain has a pH of 7; below this figure, rain is acid.





A specially tinted photograph clearly shows the fumes emitted by a car exhaust. In cities, many people – particularly cyclists – are wearing face masks to filter the polluted air (inset).

particles in smoke which can cause cancer if inhaled. One hydrocarbon, methane – the gas used for cooking – is also one of the main gases responsible for the greenhouse effect.

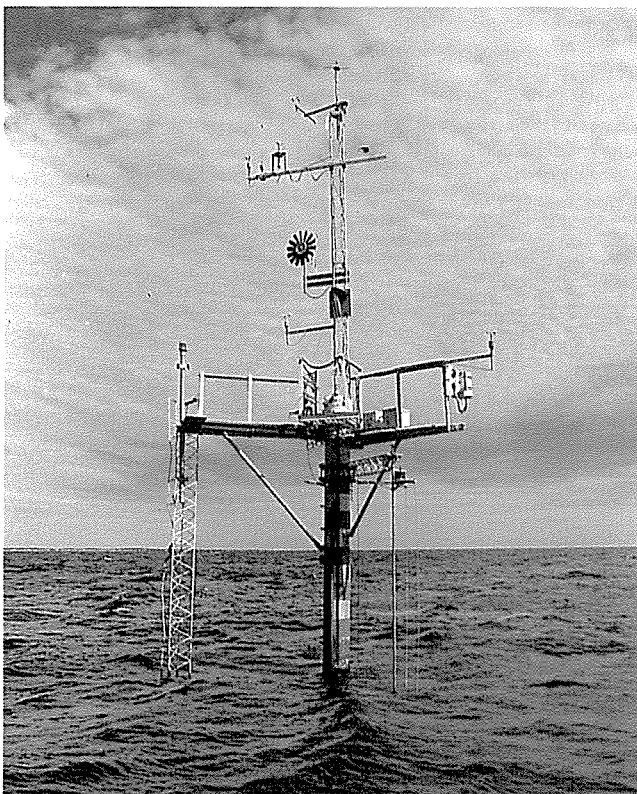
Ozone pollution

Another pollutant gas is ozone. High up in the atmosphere ozone protects us from the Sun's harmful rays. But when it is produced at ground level it is dangerous. High concentrations can damage the lungs and harm the body's defences against disease. It also damages plants, particularly when mixed with other gases like sulphur dioxide.

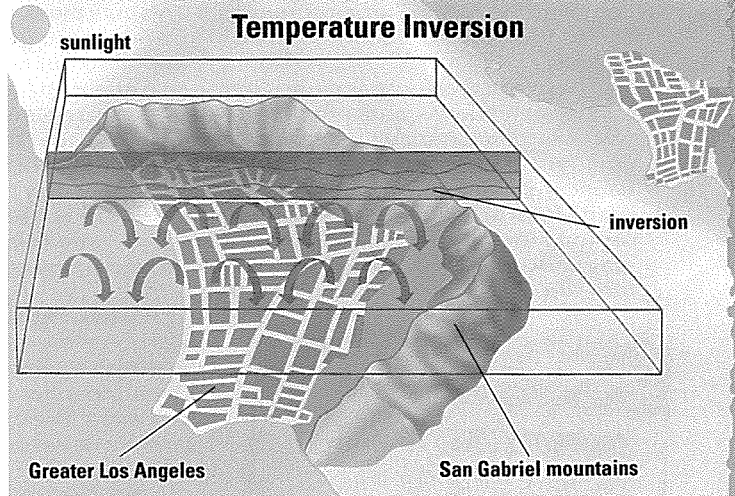
Ozone is produced by electrical equipment and by chemical reactions involving other polluting gases – hydrocarbons and nitrogen oxide – particularly when exposed to strong sunlight. And high ozone levels are

On a buoy off the New York coast, meteorological and oceanographic instruments are used to study air pollution, and the movement of polluting gases.

Rex Features Ltd



Trevor Hill



Los Angeles smog is made worse by the city's geography. The action of the Sun forms particularly harmful gases, and the wind and surrounding mountains cause a 'temperature inversion'. This traps warm air below cold, and polluted air cannot escape.

not just a problem in towns – they are also found in the countryside when the polluting gases that create ozone have wafted from the cities. European forests have been badly affected in this way: scientists have discovered that ozone in the atmosphere has caused the death of many of the trees.

Lead poisoning

One of the pollutants that comes out of the exhaust pipes of cars has been added deliberately. Small amounts of the heavy metal, lead, have been added to petrol to help engines run more smoothly. It is not burnt or changed chemically in the car's engine, so it is pumped directly out of the exhaust pipe into the air.

Airborne lead, it has been found, affects children's brains, reducing their level of intelligence. Fortunately, lead-free petrol is now widely available and many people have had their cars modified so that they can use it.

Catalytic converter

Using lead-free petrol is one simple way in which people can cut down on the pollution from cars, but it is not the only way. Having a catalytic converter fitted to your car also helps protect the environment.

Catalytic converters are boxes which are attached to the exhaust pipes of motor vehicles and are already required by law in some countries. Inside the catalytic converter is a 'honey-

comb' made of a ceramic material or metal. The surface area of the honeycomb is huge, roughly equivalent to two football pitches. It is covered with the precious metal, platinum.

Neutralizing pollution

The platinum coating causes a chemical reaction which neutralizes the polluting gases. If the car's engine is badly adjusted and petrol is making its way through into the exhaust without being burnt in the cylinders, the petrol in the exhaust gas will burn up against the platinum, leaving water and carbon dioxide.





NASA/Science Photo Library

A scientist on NASA's research craft (inset) uses laser radar to study the 'hole' in the ozone layer, said to have been created by chlorofluorocarbons from aerosols and refrigerators.

Carbon monoxide is another gas produced when petrol is not completely burnt. Catalytic converters complete the burning process, turning the carbon monoxide into carbon dioxide.

There are two types of catalytic converter: two-way and three-way. A two-way converter cuts down on the amount of carbon monoxide in the exhaust and completes the combustion of the hydrocarbons, but it does not remove the nitrous oxides. A three-way converter, on the other hand, can turn the nitrous oxides into nitrogen.

This cuts the output of toxic gases by about 90 per cent with little effect on fuel efficiency.

One problem with catalytic converters is that they can only be used with lead-free petrol. Another problem is that they do not remove carbon dioxide which passes directly through them – and this is one of the gases producing the greenhouse effect.

Cutting down on cars

Carbon dioxide traps heat from the Sun and excessive amounts of it in the atmosphere could lead to global warming. The only way to check this is to cut down on the number of cars.

But cars are not the only source of pollution. Power stations produce polluting gases too. The fumes leaving the chimneys of power stations contain sulphur dioxide and nitrous oxides. Fortunately, these fumes can be 'cleaned' by means of a Flue Gas Desulphurization Unit, or FGD. This works by trapping the acid-producing fumes in liquid limestone.

Other ways to reduce pollution from power stations is to burn less high-sulphur coal, use nuclear power stations – which have their own problems – or simply use less energy.

Just amazing!

SOMEBODY LOVES YA

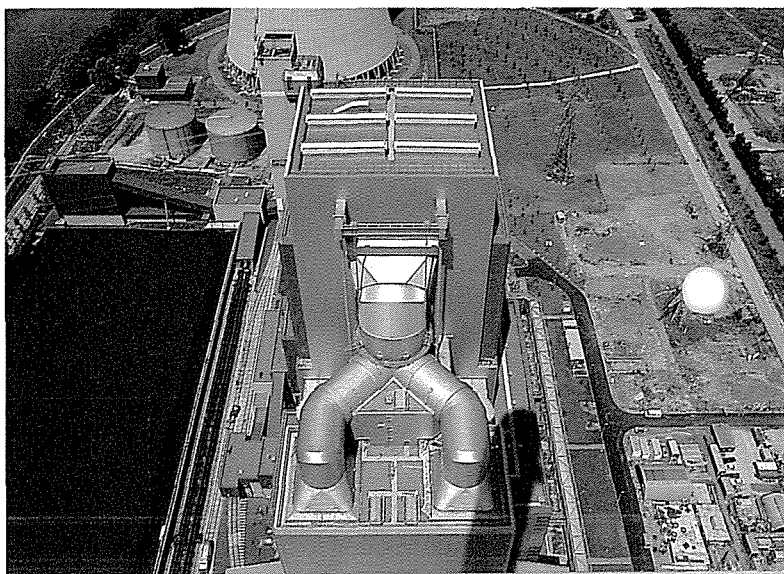
ACID RAIN IS NOT ALL BAD. ALTHOUGH STONEWORK SUFFERS WHEN IT FALLS, IT CONTAINS NUTRIENTS, WHICH ENCOURAGE PLANKTON IN THE SEA TO GROW IN ABUNDANCE.



Paul Raymond

An aerial view of Unit 7 of the Heilbronn power station in Germany shows the system used to remove nitrogen oxides from the station's waste gas. Built in 1982 with the environment in mind, the Unit also contains machinery for the removal of sulphur dioxide and dust in the flue gas.

Energie-Versorgung Schwaben AG



THE LIVING PLANET

THE EARTH IS A SINGLE living organism – not a collection of rocks and seas with plants and animals living on it. And its name is Gaia.

The idea that planet Earth is alive is probably as old as the human race. Many ancient civilizations thought of the Earth as a living goddess. But the idea achieved a new acceptance with the Space programme when men first saw the Earth from Space. The Earth with its seas and its clouds looked so different from the other, dead, planets.

Life on Mars

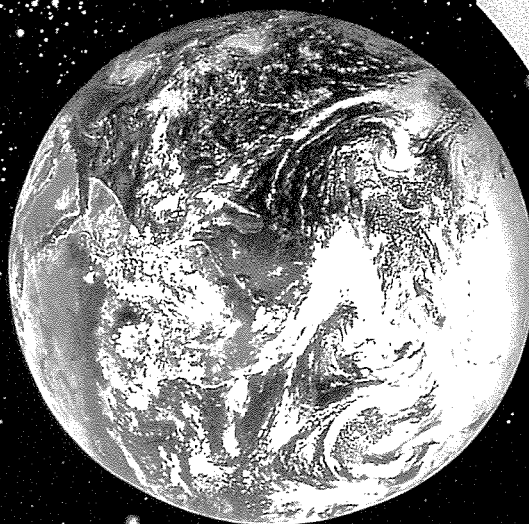
Then, when Space scientists began to send probes out to other planets – Mars in particular – looking for life, they had to think clearly about how they would recognize something living if they saw it. Life on other planets might be very different from the sort of living things we know on Earth.

There were other problems too. Say you were an alien whose idea of a living thing was an elephant. So you sent off a probe to Earth with instruments that could recognize an elephant. But if it landed in the Antarctic, it would not find any elephants and would report back that there was no life on Earth.

Explosive atmosphere

Some scientists began to realize that one way an alien would be able to tell that there was life on Earth was by analyzing the atmosphere. It contains gases like methane and nitrogen. These gases exist in the atmosphere along with the highly reactive gas oxygen – practically an explosive mixture. If there were no life on Earth these gases would react, form compounds and eventually deplete the atmosphere until it became sterile carbon dioxide like that of the dead planet, Mars.

When men first left the Earth, they noticed that its beautiful blue ball looked almost as if it was alive. An alien would easily be able to see that there was life on this planet from Space without landing on it – just as some scientists say it is possible to tell that the barren surface of Mars (inset) is lifeless without sending a probe there.



ZEFA

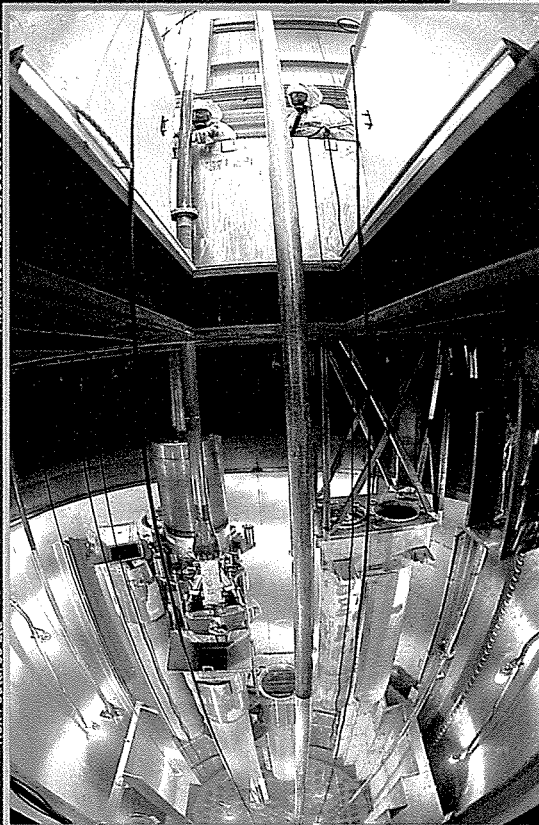
Gamma/Frank Spooner Pictures



Industrial pollution can be deadly. These two scientists have to resort to full protective clothing and breathing apparatus to take a sample of contaminated water.

Oil washes ashore in Alaska in March 1989, after the Exxon Valdez struck a reef and deposited 11 million tonnes of oil in Prince William Sound.

Alexander Jarras/Science Photo Library



Nuclear weapons used to be tested at ground level, or in the air. This threw enormous amounts of radioactive dust up into the atmosphere. Now they are tested underground.

Engineers practise emergency procedures at Three Mile Island. The clean-up after an accident in 1979 will be completed in 2019.

Raw pollution is pumped into a river in the Czech Republic. It will flow into other countries.

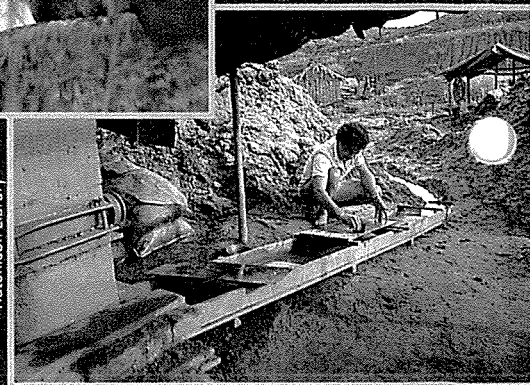
Peter Parks/Oxford Scientific Films



Can carriers can get around the necks of sea birds and strangle them as they grow.

Mercury used in gold extraction in South America washes into a stream, poisoning it.

Hutchison Library



Crop spraying in the Napa Valley in California causes atmospheric pollution and contaminates the surrounding area.



- Q FOOD CHAINS
- Q PITCHER PLANTS
- Q TOP PREDATORS

WORLDS WORLDS

ALL LIVING THINGS ARE inter-dependent. They interact with each other and with their environment, both on a small scale and on a large scale – from a rotting branch to the planet-wide biosphere. These spheres of interdependence are called ecosystems.

Food, in some form, is needed by every living creature, to grow, reproduce and repair itself. Green plants can make their own food by taking in very simple substances together with energy from the Sun.

Rotting bodies

Some animals – herbivores – eat green plants as a source of ready-made food, while others – carnivores – feed on the plant-eaters or smaller meat-eaters. And when both predators and prey die, their rotting bodies provide nourishment for plants and microscopic life-forms so that the cycle can continue. Such a food chain lies at the heart of every ecosystem.

Richard Kirby/Oxford Scientific Films



Lake Baikal in Siberia contains about one-fifth of the world's fresh water. Despite its size, it is a unique ecosystem. More than 1,000 of the species that live there, live nowhere else on Earth. The lake's top predator is the Baikal seal (left).

Doug Amani/OSF

Among the smallest and most unusual ecosystems are the water-filled traps of pitcher plants. Like the Venus flytrap, pitchers tend to grow in poor soil where few other plants can survive. To make up for the lack of nutrients in the soil, they catch small insects in trumpet-shaped leaves that hold special digestive juices, diluted

with rainwater, to form a small pool.

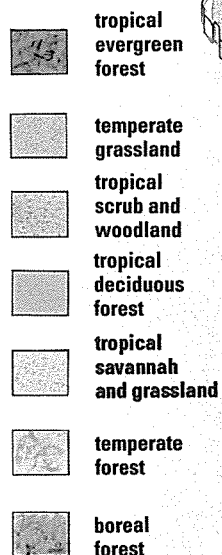
Lured by nectar at the rim of the pitcher, a variety of flies and other insects tumble down the steep sides of the leaves into the pool at the bottom. But as the victim's bodies are broken down, they supply food not only to the pitcher but also to a community of tiny creatures that live inside it. Swim-

ming around in the pitcher pool are the larvae of biting midges and mosquitoes, together with small mites. These, in turn, are the prey of hoverfly larvae that lurk close to the water on the sides of the pitcher.

Tree stumps and broken bamboo stems, in the tropics, also collect rain water that supports communities of



Vegetation Of The World



The major vegetation belts are huge ecological communities of plants and animals. Particular species are confined to areas called biomes. These vegetation belts or biomes are limited by rainfall, soil type and mountains.

various larvae, snails and free-swimming crustacea similar to shrimps. Heading these miniature food chains is sometimes a 'top' predator — a single dragonfly nymph that hides deep in the pool ready to feed on anything it can creep up on. These top predators are like the lion, eagles and sharks of large ecosystems on the planet.

Self-contained ecosystems, such as pools in plants, give scientists the

chance to work out in detail the way energy enters the system and the way species depend on one another. On a huge scale, Lake Baikal in Siberia offers the same opportunity.

With an age of 20 to 25 million years and a depth of 1,637 metres, Lake Baikal is the oldest and deepest lake in the world. It also contains the most species. Of the 1,550 different types of animals and 1,085 varieties of plant that live there, more than



Keith Scholey/Planet Earth Pictures



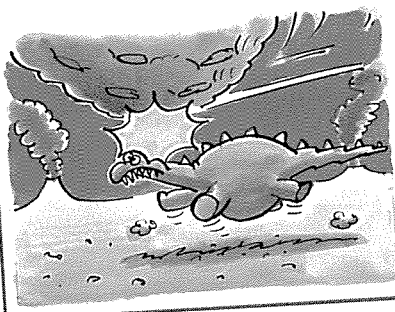
Peter Parks/OSF

Tiny ecosystems form in pools in plants. The pitcher plant contains a whole community of creatures who live on the victims that the plant catches. This fly (left) was lured by the plant's nectar. It fell down the steep sides of the pitcher to provide a solid meal for the plant and the larvae that live in it.

Just amazing!

THE COSMIC CULL

ABOUT 65 MILLION YEARS AGO, OVER TWO-THIRDS OF ALL THE SPECIES ON EARTH BECAME EXTINCT. THE CAUSE MAY HAVE BEEN A COLLISION WITH A TWO-KILOMETRE-WIDE ASTEROID.



Paul Raymonde

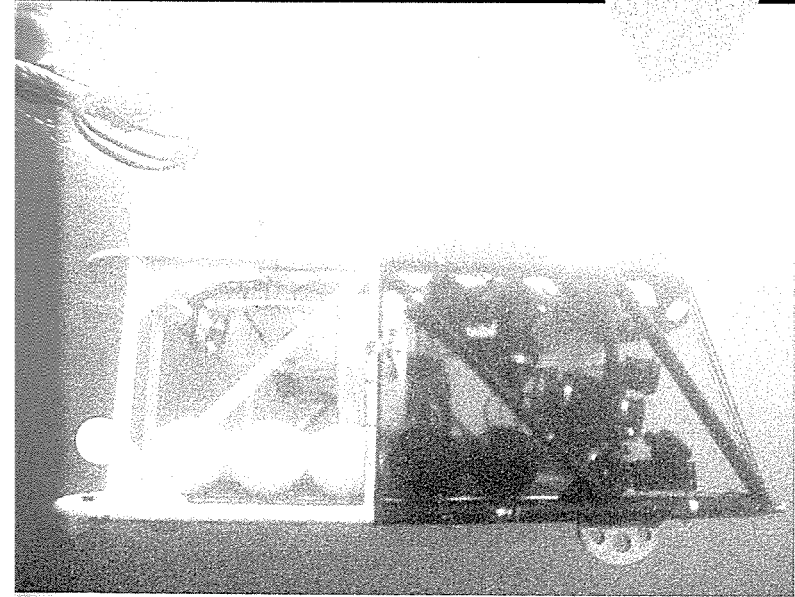
1,000 occur nowhere else on Earth.

Sunlight falling on Baikal promotes the growth of phytoplankton — tiny, single-celled plants — which microscopic animals, or zooplankton, feed on. Both types of plankton are eaten by numerous types of small animals, such as the lake's many species of shrimp. The shrimp and small fish become food for bigger fish, which in turn are eaten by the lake's largest predator, the unique Baikal seal.

An ecosystem such as that of Baikal can be easily upset, however. This was demonstrated in the 1960s when a shrimp-like amphipod was introduced into California's Lake Tahoe. The idea was to provide extra food to boost Tahoe's trout and salmon population. But the experiment backfired. Instead, the new amphipod wiped out two of the lake's native species of zooplankton, cutting the fishes' food sources rather than enhancing it.



SLIPPING AND SLIDING



The Andes run 7,200 km down the western edge of South America. They were thrown up by volcanic activity when the oceanic Nazca Plate started to slip beneath the South American Plate.

An unmanned submarine collected data about the movement of plates in the ocean. The survey was sent onboard into the television and video cameras.

THE LAND WE STAND ON MAY seem still enough. But, in fact, it is moving all the time. The continents drift very slowly around the surface of the globe – and sometimes they bump into each other.

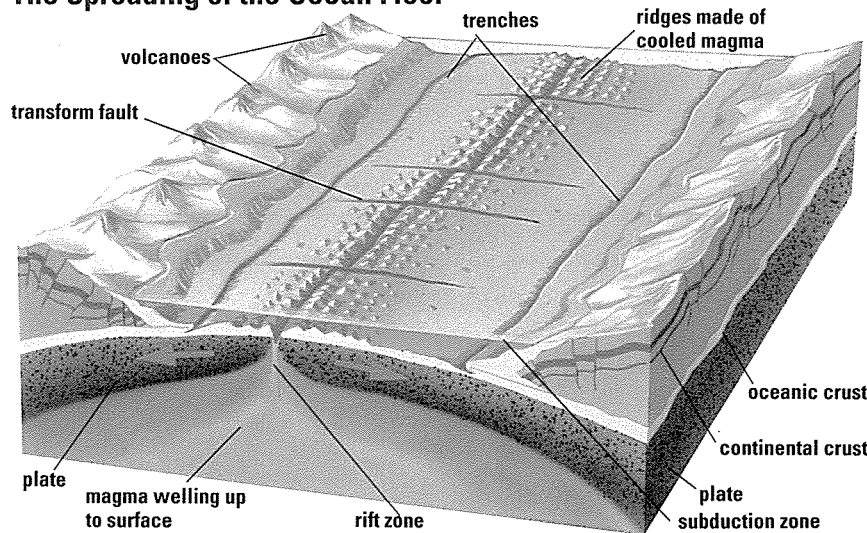
If you look at the east coast of the Americas and the west coast of Europe and Africa, it is not hard to see that they fit together like two pieces of a jigsaw. Brazil fits into the Gulf of Guinea. The bulging coast of Guinea, Senegal and Mauritania nestles into the Caribbean and the broad sweep of the eastern seaboard of the United States. Newfoundland slots into the Bay of Biscay, while Greenland neatly plugs the gap between Scandinavia and Baffin Island in Canada.

This was once dismissed as mere coincidence, but now it is recognized that all the continents did once fit

Koblmueller/ZEFA



The Spreading of the Ocean Floor



***Ocean floors** are constantly being renewed. Magma wells up through cracks in the crust where two plates are pulling apart, spreads out and cools in ridges, forming new crust. The Mid-Ocean Ridge System (right) runs through all the oceans.*

together and have gradually split up and drifted apart.

Some 250 million years ago there was only one continent – Pangaea. All the land masses of today, along with their continental shelves – the area of shallow water around a continent that is in fact part of the continent itself – fitted together like a jigsaw.



Supercontinents

Then around 200–180 million years ago Pangaea split into two vast supercontinents – Gondwanaland and Laurasia. Gondwanaland comprised what are now Africa, Australia, Antarctica, South America and India. Laurasia contained Europe, North

America and Asia without India.

During the next 150 million years, Gondwanaland and Laurasia themselves broke into pieces. North America began to part from Eurasia, although the separation was not complete until about 40 million years ago. South America began to separate from Africa about 135 million years ago and India separated from Antarctica about 105 million years ago. Finally, Australia and Antarctica split. Ever since they first split, the continents have been moving apart at the

HUMAN MIGRATION

The continents first drifted apart long before Homo sapiens appeared on the scene. However, during the period 50,000–10,000 years ago the climate did affect mankind's settlement of the Earth. The expanded polar ice caps locked up so much water that sea levels fell by over 100 metres. Men and women walked from Asia into North America, across the dry sea-bed of the Bering Straits. They also migrated from Southeast Asia into Australia, using Indonesia as a land-bridge. When the ice caps melted and sea levels rose again, Native Americans and Aboriginal people of Australia were separated from their Asian neighbours.

***The rift** that runs across south-east Iceland is caused by two plates pulling apart. The whole island is part of the Mid-Atlantic Ridge and made of cooled lava.*

rate of a few centimetres a year.

The continents sit on huge tectonic (from tekton, Greek for builder) plates. It is the plates that are slowly moving. The Earth's outer shell, called the lithosphere, is divided into nine large plates and a number of smaller ones. There are three oceanic plates: the Pacific, Nazca and Cocos Plates. The major continental plates are Eurasia, Africa, North America, South America, India-Australia and Antarctica.

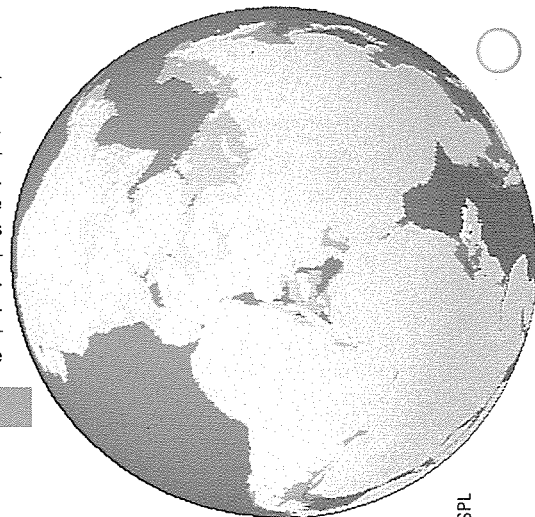
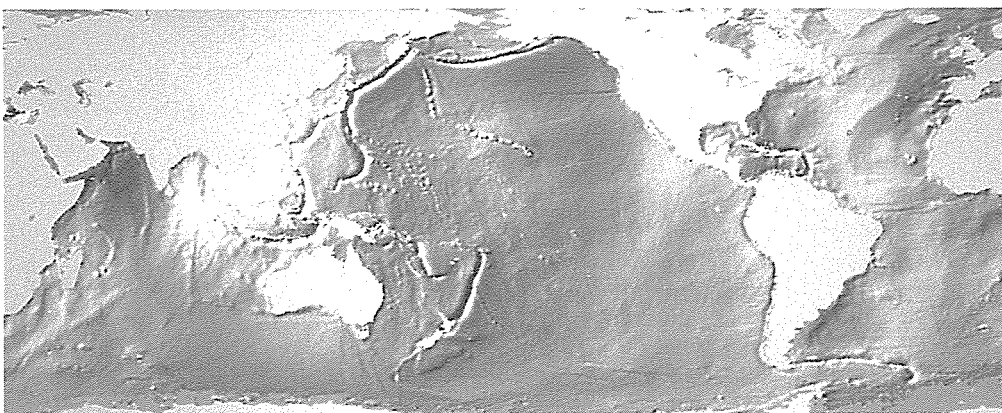


The Earth's crust

However, the shape and size of the plates do not follow those of the continents. Most plates include both continental and oceanic crust. The continents, mostly made of granite, ride the plates, which are made of

Paul Williams

NASA/Science Photo Library



***Earth had just one continent** 250 million years ago, which we call Pangaea. It has since split up into the continents that exist today.*

denser (heavier) basalt. The plates form a rigid layer, 90–100 km thick, which floats on a hot layer of semi-fluid rock that forms the upper mantle.

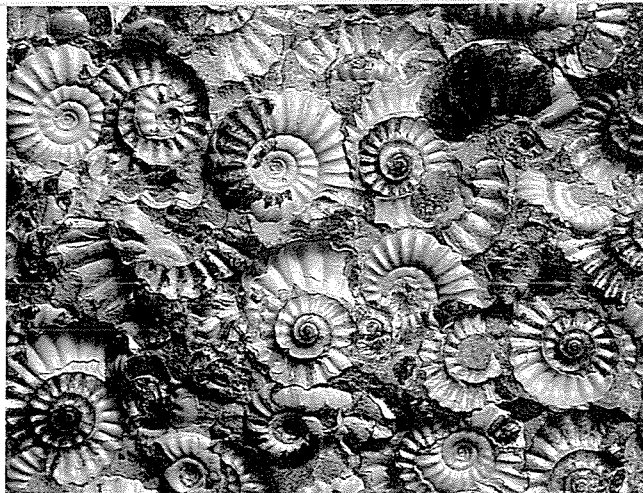
Boundaries between plates are marked by:

- ridges or rifts, where the plates are being pulled apart
- faults, where two plates are sliding past each other
- subduction trenches, where two plates collide and one of them is thrust under the other and descends, often quite sharply, into the mantle.

Dr S Gull & Dr J Fielden/SPL



Fossilized ammonites – a type of marine mollusc. Marine fossils such as these are sometimes found high up in mountain ranges where both continental and oceanic crust have crumpled into fold mountains, because the continental crust is too buoyant to slide down a subduction trench.



Running down the middle of the floor of the Atlantic Ocean is a huge ridge, where molten rock pushes its way up through the crack between two plates. As the molten rock emerges, it cools, forming a ridge of new rock. This continuous process is causing the Atlantic ocean floor to expand at a rate of 1-9 cm every year. The stress created by two plates pulling apart tears transform-faults across the crust, which lie at right angles to the rift zone.

This is just part of a mid-ocean ridge system that runs through all the

An oil pipeline running across the active Denali Fault in Alaska, USA, is on skids so that it will not break when the fault moves.

Great Rift Valley that runs 3,000 km down eastern Africa. The crust fractured on each side of the stressed area, allowing the area in between to drop. The sea has not broken through and flooded the Great Rift Valley – yet. But ultimately east Africa will break off from the rest of the continent.

When two plates push or slide against each other, a series of shock

est trench of all – plunging 11,000 metres below sea level – is the Marianas Trench, where the Pacific Plate descends under the Philippines Plate.

A descending plate may be carrying a continent. In this case, the lighter, less dense, continental crust resists



subduction – it dives into the trench with the oceanic crust, but is too buoyant to sink into the mantle. This crumples its leading edge into folds and throws up a range of mountains. When two continents converge over a subduction zone, the result is even

A rock face in the Swiss Alps. The Alpine chain of fold mountains were formed when the African Plate rammed into Asia.

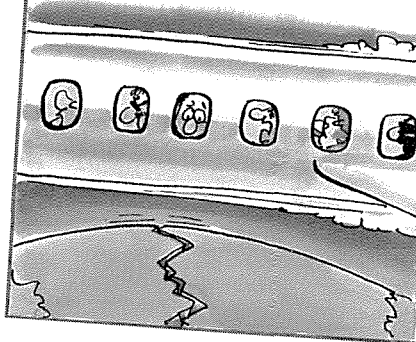


The Grand Canyon, in Arizona USA, is so deep (a staggering 1.6 km) because the surrounding land was slowly being thrust upward as the Colorado River cut downwards.

Just amazing!

LATE ARRIVAL

EVERY YEAR CONCORDE TAKES AN EXTRA ONE TEN THOUSANDTH OF A SECOND TO FLY FROM NEW YORK TO PARIS, BECAUSE NORTH AMERICA AND EUROPE ARE SLOWLY MOVING APART.



Paul Raymond

oceans. The peaks of these underwater mountains occasionally emerge above sea level, as is the case with Iceland and the Azores, which are both part of the Mid-Atlantic Ridge.

The Great Rift Valley

Sometimes, magma welling up from below heats the continental crust and forces up a dome. The dome cracks to form a Y-shaped rift. A good example is the triple rift between Africa and Arabia. The three arms of the rift are the Red Sea, the Gulf of Aden and the

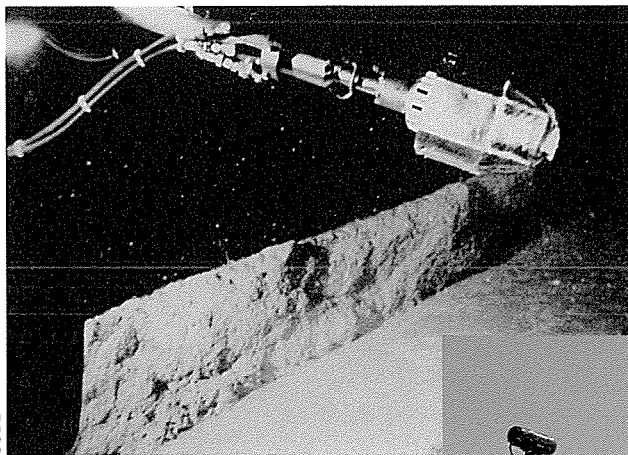
waves are generated – an earthquake. The major earthquake zones of the world follow the boundaries of the Earth's plates. (See PLANET EARTH pages 101-4.)

When two plates collide, the less dense plate rides over the edge of the other plate. The edge of the denser plate turns downwards and begins to plunge into the semi-liquid mass on which the plates float. The angle at which it sinks varies from a gentle slope to a steep 45°. As it descends, it forms a subduction trench. The deep-



Core samples – cylinders of sea-floor sediment and rock – are analysed for information on the age of the oceanic crust and its formation. To take a sample, a long drill pipe edged with a sharp bit is lowered from a specially equipped drilling ship.

IOSDL



the Earth is getting bigger. The ancient supercontinent would cover a globe with a diameter just over half that of the Earth today. It is possible to imagine that the Earth was once covered by a single landmass. As the Earth expanded, some speculate, the supercontinent broke up, with molten rock exuding from the cracks.

Scientists use submersibles to get high-resolution photographs of the ocean floor, to take magnetic readings and to obtain samples. The mechanical arm (above) of submersible *CYANA* collects fragments of rock from the floor of the Atlantic, west of Ireland.



more spectacular. The Himalayas were created in this way.

As a cold, brittle plate slides down a subduction zone, it generates a series of earthquakes. Friction on the descending plate and heat from the mantle causes melting, at a depth of 60-120 km. Magma rises to the surface of the overriding plate, erupting as lava. The lava hardens on the surface, forming volcanoes and adding new material to the continental crust.

A few scientists hold a theory that

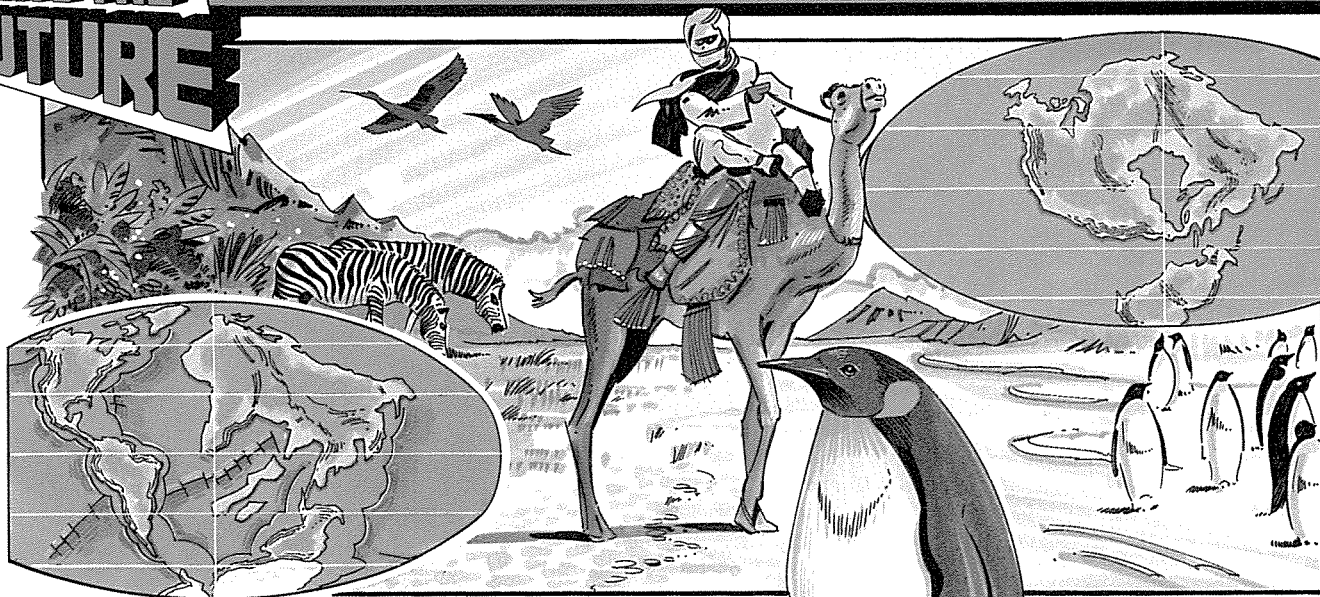
This would explain some phenomena that the theory of plate tectonics does not adequately account for. For example, all the plates are moving northwards away from the Antarctic Plate, which is itself expanding, and converging on the Arctic. Yet tests show that oceanic crust in the far north is expanding too.

But there is no direct evidence that the Earth is expanding. If it is, the yearly rate of expansion, perhaps about 1 mm, is too tiny to measure.

Gamma/Frank Spooner Pictures

INTO THE FUTURE

WHEN CONTINENTS COLLIDE



▲ If Africa continues to move northward, it will eventually join up with Europe, replacing the Mediterranean Sea with a new mountain range.

▲ Africa's Great Rift Valley could come apart, creating a sea connecting the Atlantic and Indian Oceans. Antarctica may move north, until it grinds into Australia.

▲ In 250 million years time the continents may have drawn together, once again, into a single land mass, with former coastlines marked by chains of fold mountains.

Joe Lawrence



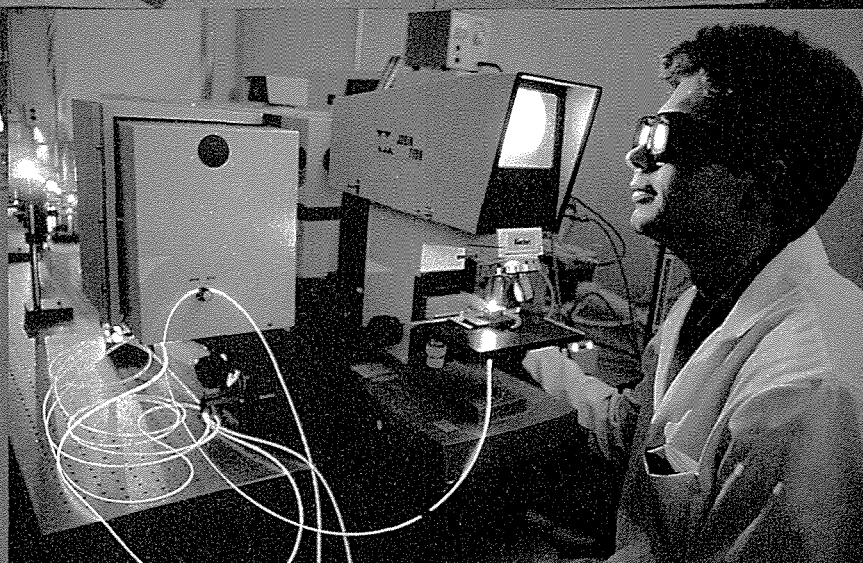
Q TIME DIVISION

Q OPTICAL FIBRES

Q CABLE LAYING

CABLE TALK

The cable ship Mercury weighs 8,962 tonnes and is capable of carrying 3,000 tonnes of cable. Between 1983 and 1990, the ship laid 9,500 km of cable.



Cable & Wireless (Marine) Ltd
Hank Morgan/Science Photo Library

UNDERSEA CABLES WERE THE arteries which carried the world's communications long before satellites were launched to beam messages around the world. Even now, nearly half of all intercontinental telephone traffic travels along the bottom of the world's oceans and seas.

The longest modern undersea system is the ANZCAN cable, which runs more than 15,000 km, from Australia via Norfolk Island, Fiji and Hawaii to Port Alberni, Canada.

A telephone works by converting variations in sound to variations in

electric current using a microphone in the mouthpiece. The electrical signal then travels to the receiving set. However, this signal gradually weakens and, over long distances, results in the loss of signal strength at the receiver.

Signal boosting

In overland phone systems, it is a relatively straightforward matter to install amplifiers, or repeaters, along the line at regular intervals. These boost the signals and enable communication over hundreds or thousands of kilometres. The repeaters are supplied with electricity from a local

power source and are easy to get at for maintenance or replacement.

Undersea, or submarine cables, on the other hand, pose a much greater problem. If a repeater breaks down on the seabed it is very expensive to repair. The system must, therefore, be highly reliable and, since it is expensive to manufacture and install, great

Monitoring the quality of the optical fibre during its manufacture is important. Here scattered light is measured to check just how much is lost from the sides of the cable.



Undersea Telecommunications Cables

Across the world fibre-optic cables are replacing analogue ones. The last analogue cable was laid in 1987, between India and the United Arab Emirates. The main map shows the major cables in the world, whilst the inset of Europe shows the many minor links.

repeaters
every 100 km

Europe

Asia

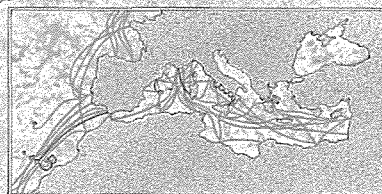
Africa

repeaters
every 48 km

South America

Australia

■ optical cables
■ analogue cables



Simon Critchley

emphasis has been placed on providing the greatest number of telephone channels along a single cable.

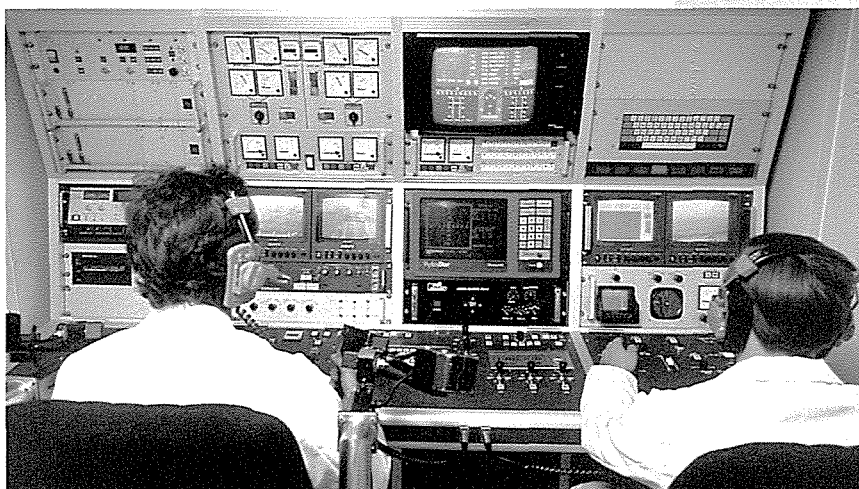
Any two telephone sets that are in communication are connected by two wires, one for receiving and the other for transmitting messages. Normally, it is possible to transmit and receive on the same pair of lines at

frequency from the signal moving in the opposite direction. Furthermore, in order to avoid providing one set of wires each with its own amplifier and booster for each telephone connection, ways of combining a large number of conversations to pass along a

single wire and through a single amplifier have been used.

On analogue cables the telephone channels are modified in frequency and are stacked into a broadband signal. The transmit and receive signals

Cable & Wireless (Marine) Ltd



either end. This cannot be done with an undersea system because of the problem of arranging for the switchover from 'transmit' to 'receive' when the direction of transmission changes. So, for two-way communication, two channels have to be provided for each pair of users.

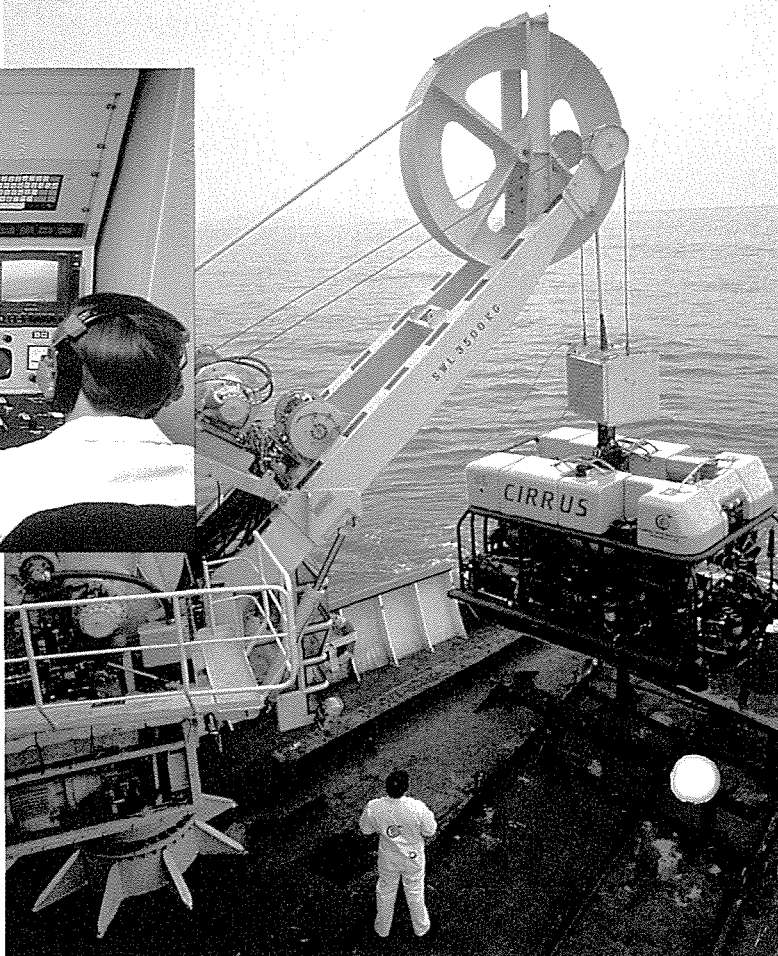


Two-way traffic

Early systems used two sets of cables, one for each direction. But modern systems employ a single cable, with the signal travelling in one direction transmitted at a different

Remote operated vehicles (ROVs) can repair cables to a depth of 1 km.

From a control room (above) the engineers manoeuvre the ROV to the cable and operate its video cameras, articulated arms and the powerful water-jet trench digger.



stations, A and B, situated on opposite sides of the Atlantic. Signals from terminal station A to B pass through a low-frequency pass filter, into the amplifiers, out through a further low-frequency pass filter, back into the cable and so on to terminal B. The B to A signals pass through high-frequency pass filters at each end of the amplifier. Using this technique single cables carrying as many as 5,000 simultaneous telephone conversations have been constructed and are in

Cable tanks on the ships can each carry 5,300 km of cable. The ships have either three or four of these gigantic tanks.

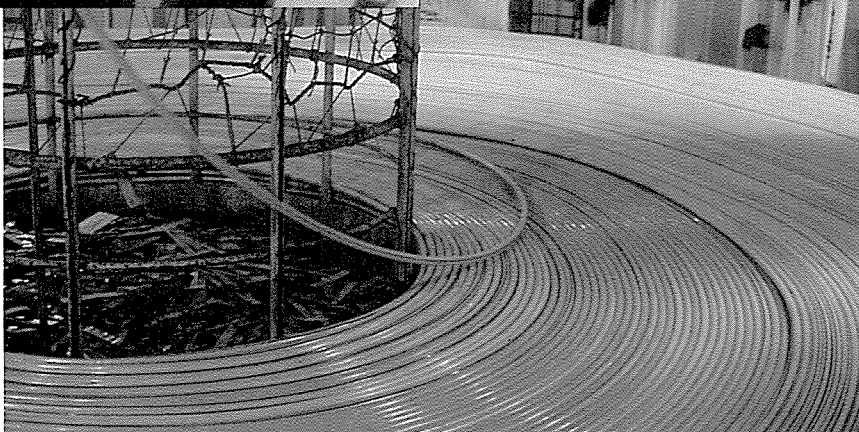
Cable & Wireless (Marine) Ltd

On-board repairs are necessary for cables in water over 1 km deep. On each ship a team of ten highly-skilled engineers work on the hair-like optical fibres.

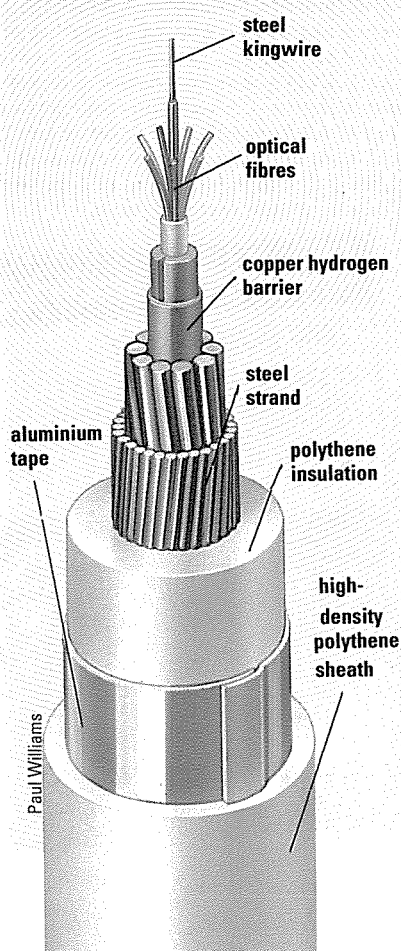
are stacked in two different frequency bands so that they may pass in two directions along a single cable. This is called frequency division multiplex.

To make sure that signals in the correct frequency range pass in the right direction, special electrical devices called pass filters are built into the repeaters.

Take, for example, two terminal



INSIDE AN UNDERSEA CABLE



The precision-made optical fibres (below) in the centre of the cable are coated in acrylic resin and colour coded for easy identification. They are arranged around a central wire and embedded in a protective gel. A double-layer copper tube surrounded by strengthening steel wires carries the power feed current.

Finally, a sandwich of aluminium tape and polythene insulates the components. The aluminium prevents the electric field radiating into the sea and attracting sharks. The outer, high-density polythene sheath completely waterproofs the cable and is resistant to penetration by sharks' teeth.



Philippe Plailly/Science Photo Library

daily use throughout the world.

Modern telephone systems employ digital techniques. These provide clearer and more compatible systems to the large amounts of data from, for example, the increasing number of computers and fax machines.

Light pulses

Digital signals are also eminently suitable for sending information longer distances along optical fibres using modern laser technology. For these systems the speech signal is converted into digital light pulses. Because the submarine cable can contain up to 12 optical fibres, one fibre is used, just as in the early analogue cables, for each direction of the speech path.

In digital cables a technique called time division multiplexing is used. Here, each conversation is sampled 8,000 times per second. Each sample is characterized by eight bits of information.

Each bit of information may be shortened in time and interleaved with bits from other telephone channels. At the receiving end the individual bits of each conversation are retrieved



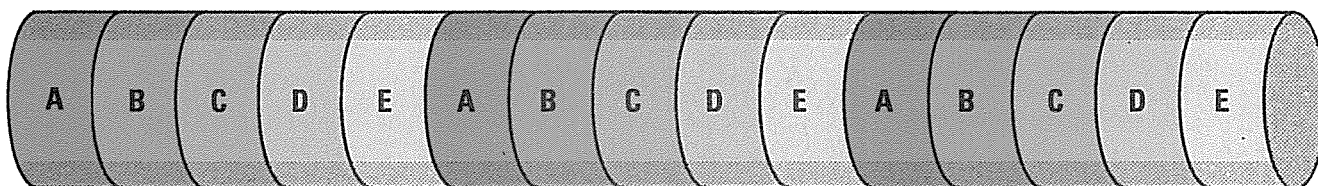


Inland optical fibre cables have been used by British Telecom in the Trunk Network since 1980. Engineers patch the new undersea optical cables into the system as they are laid.

only a few ships are equipped for this purpose. Great care has to be taken that the cable is paid out at a constant rate and under constant tension to avoid kinking or stretching.

Hydraulic grips

While laying cable, the ship sails at a steady speed of about 9 km/h. The cable and repeater units are paid out using a linear cable engine. This is essentially a series of pairs of rubber-tyred wheels, which are pushed together using hydraulic activators, thus gripping the cable. When a repeater passes through the engine, the wheels open further apart to accept the increased repeater diameter.



Time division multiplexing works by allocating phone call A a burst of time – one twenty thousandth of a second. Then B, C, D and E will each be allocated a similar burst. These bursts and the gaps between are so small that each conversation seems continuous.

Repeaters need to be constructed to very high specifications. They have been laid in the Mariana Trench, the world's deepest point underwater at 10,924 metres. The pressure at this depth is 1.1 tonnes per cm^2 , compared to the 1 kg per cm^2 at sea level.

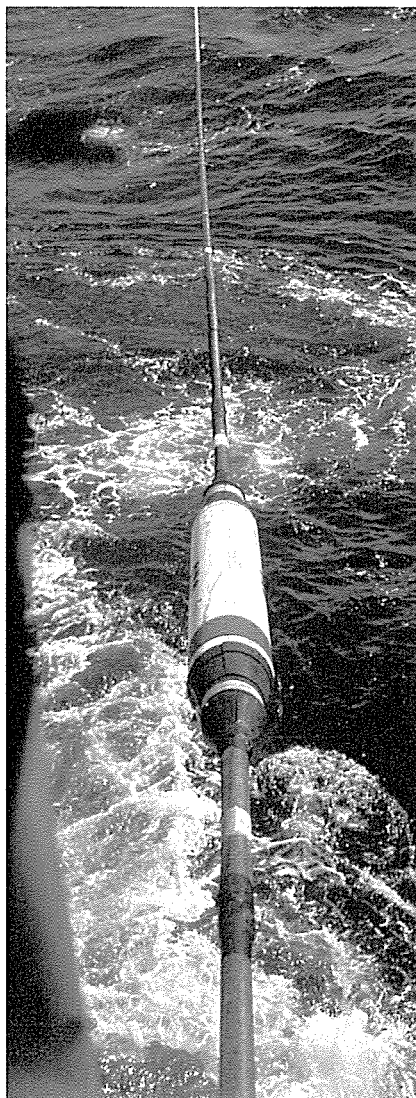
and the speech signal is reconstructed. Although our ears hear the bits discretely, the brain fills in the gaps between the bursts of conversation and we fail to notice anything wrong.

In the undersea repeater, the incoming light pulse is detected, converted into an electrical pulse, amplified, retimed and then used to switch a laser light pulse on and off before being returned to the cable. Optical submarine cables currently installed across the Atlantic and Pacific Oceans contain about 4,000 telephone conversations per fibre pair and the repeaters are spaced about 100 km apart.

Transatlantic chatter

The latest development is the transatlantic cable that can carry 8,000 telephone conversations per fibre. For this system the digital signal pulses are at the rate of about 600 million per second.

Laying undersea cables and repeaters is a highly specialized job and



Each repeater is about 3 metres long, about 30 cm across and weighs about one tonne. To avoid damaging the relatively fragile repeaters as they are lowered over the side, the ship slows to about 3 km/h.

High-risk sites

In shallow waters, where the risk of damage from fishing trawls, anchors, and grounding icebergs is higher, armoured cable is used. In very hazardous areas the cable is buried beneath the sea bed with the aid of a ship-towed plough. The cable is laid in the furrow dug by the plough and is refilled as the back of the submarine plough travels over the cable.

Just amazing!

LONG-DISTANCE WIRE

ENGINEERS LAYING A CABLE FROM NEWFOUNDLAND TO THE AZORES IN 1932 USE A 'TAPE MEASURE' MADE OF 2,340 KM OF PIANO WIRE.



Paul Raymond

SECOND

SIGHT



Starry skies often seem to contain 'pictures'. The human mind tries to impose a pattern on the complete randomness of the stars' positions.

Gamblers often believe they can beat fruit machines with a 'lucky touch' or a 'system'. But the machines are precisely controlled by computers.

PSYCHIC EXPERIENCES seem to be a common occurrence. Most people claim to have experienced telepathy or had a dream that came true. But why? Does the paranormal really exist or are these experiences just an illusion?

Parapsychologists, scientists who study the paranormal, have spent over a century looking for evidence of extrasensory perception (ESP) and psychokinesis (PK), or mind over matter. They have had some significant results, observing all kinds of happenings which have no logical explanation. However, the successes have to be balanced with seemingly

paranormal experiences that have more mundane explanations.

Some of these would-be paranormal experiences are just illusions, like visual illusions. These occur when our minds look for meaning or pattern when it is not really there.

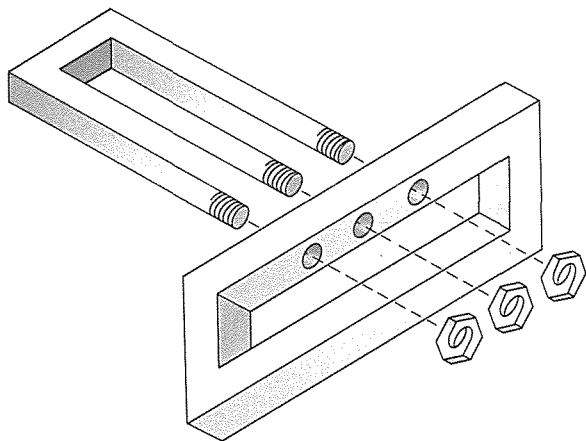
Connections

Likewise, our minds search for connections which are not there when we are faced with events that we cannot explain. But because our brains are good at finding these connections we fall for the illusion of the paranormal. However, these seemingly paranormal occurrences may be a simple lack of understanding of the

nature of chance and probability.

You may be thinking of a friend, for example, who you have not heard from for ages. Then the phone rings and it turns out to be the friend you have just been thinking of. If you believe this to be an unlikely coincidence you will look for an explanation. If you cannot think of a 'logical' explanation – like she always rings just before Christmas – then you may think it was psychic. Somehow the mind cannot accept coincidences as just that but has to find a more comforting explanation. However, it may not be such an unlikely event at all. You may think of many people every day but you forget all those thoughts which do not





Optical illusions rely on the mind's capacity to look for answers. Here, at first, the figure looks possible but on examination we see it is not.

people a year in Britain alone to have such a death dream come true. Those 25 people will almost certainly think they are psychic when, in fact, only chance was operating.

Thought control

PK experiences may also be illusions. A well-known psychological effect is called the 'illusion of control'. When an action you make coincides with a random event, the mind tends to jump to the conclusion that you have caused the event. You may feel you can control traffic lights by simply willing them or change the shape of clouds by the power of your mind. This is one of the strongest illusions of control.

Parapsychologists call believers in the paranormal 'sheep' and disbelievers 'goats'. One of the experiments involved a group of sheep and a group of goats flipping a

coin 20 times. Asked how many they would be able to guess right by chance, the goats said, on average, close to ten. Using the laws of probability, ten times is about the right amount you would expect to guess the side of the coin correctly. The sheep believed they would be able to guess less than eight. So if the coin flips randomly and they guess right ten times they delude themselves into thinking that they have done particularly well. Then in the absence of any other explanation, they will think they are psychic. So some psychic experiences may not always be proof of the paranormal but a powerful illusion caused by the way our minds work.

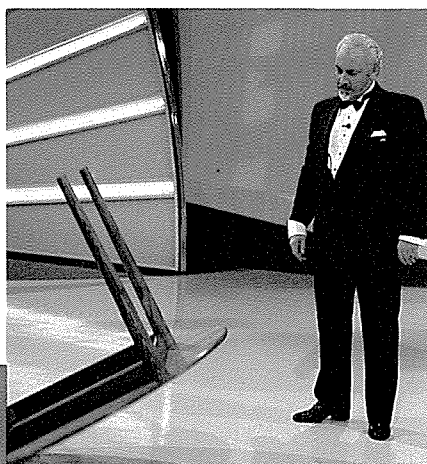
coincide with anyone ringing. Finding yourself singing the same song as someone else may be a result of both of you unconsciously hearing it on a passing car radio. In the same way a song, subconsciously heard, or even smelling an odour or seeing a picture on the wall, can set off the same train of thoughts in two people who know each other well.

The most dramatic and convincing of ESP experiences are dreams of death that come true. However, a statistician estimated that purely by chance you would expect about 25



Sue Blackmore

An illusionist tries to persuade the audience that he or she possesses psychic powers. Here David Berglas appears to be moving the table solely by psychokinesis. But it is no more than an elaborate and ingenious trick.



Telepathy experiments using special picture cards aim to determine whether ESP picks up form and colour or the written word more easily. A child is asked to concentrate on a particular card, whilst another child in a separate room is asked to pick out which card is being thought about.

CHANCE PROBLEMS

It is amazing how we can misunderstand and misinterpret instances of chance and probability. Here are three probability puzzles to test your mental powers.

Q – A couple have five girls. What is their next likely to be?

A – It could be either. If you said 'boy' you have fallen for the 'Gambler's Fallacy'.

Q – How many people must come to a party to have an even chance that two have the same birthday?

A – Just 22. Think how many possible pairs that makes.

Q – Using only the numbers 1-5, write a list of 50 numbers and try to make them random.

A – How often did you write the same number twice in a row? A random list should have about ten repeats.

© Thames Television

Just amazing!

MONKEY BUSINESS

A MILLION MONKEYS TYPING AT RANDOM WOULD NEED LONGER THAN THE AGE OF THE UNIVERSE TO WRITE ONE SENTENCE BY CHANCE.



Paul Raymond



 **AQUIFERS**

 **HYDROFRACTURING**

 **SEALANTS**

HOT ROCKS

THE EARTH'S CRUST becomes hotter at a rate of 2.3°C with every 100 metres depth. This means that vast amounts of heat are potentially available as an alternative energy source to nuclear or fossil fuels.

Geothermal temperature varies from place to place and is dependent upon the thickness of the rocks, the presence of magma (molten rock) and radioactive elements.

Geysers

Water seeping through permeable rock or fractures near molten rock becomes heated and can develop into extensive underground reservoirs (called aquifers). Sometimes this water rises to the surface where it forms boiling pools, steam vents and geysers, such as those found in Iceland, New Zealand or in the Yellowstone National Park in the USA.

Most geothermal power stations tap this hot water energy by drilling deep boreholes to reach naturally occurring hot aquifers. As this water surges to the surface, the pressure de-

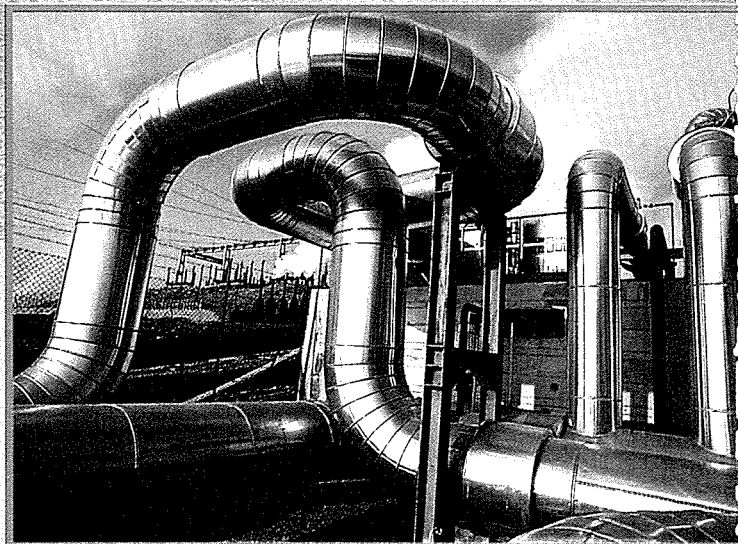
Geothermal plants produce about 5,000 megawatts of electricity worldwide. This is enough to run 1.7 million electric kettles or 5 million one-bar electric fires, simultaneously.

creases and it boils. The resulting mixture of steam and water is separated and the steam piped off to drive turbines as in a conventional power station. The waste water is reinjected into the aquifer, both for disposal and to prevent the depletion of water.

In the last few years, however, a new system of tapping geothermal power has been suggested. Rocks

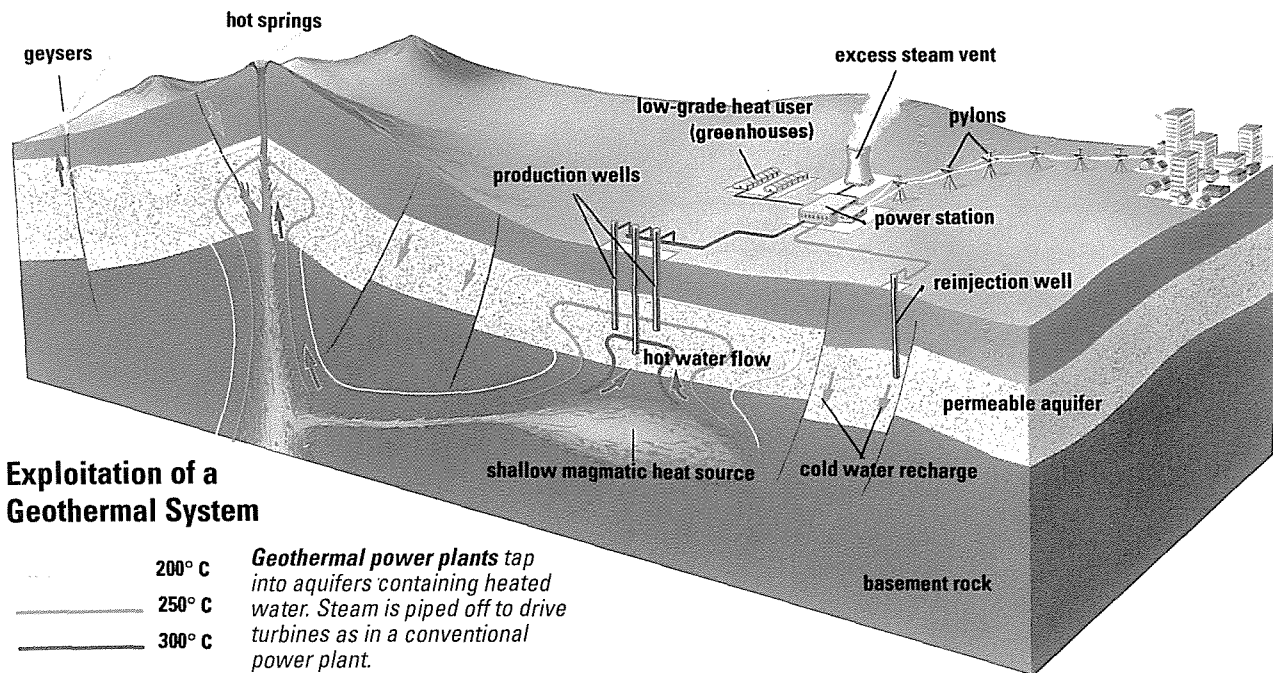
such as granite are naturally radioactive, reaching $200\text{--}250^{\circ}\text{C}$ about 6 km below the surface. Unfortunately, most of these strata do not have natural water flows to transport their heat to the surface. The new method, called hot dry rock technology (HDR), involves pumping water through these deep layers of rock, which act like a giant heat exchanger.

Mats Wibe Lund



Berenguer/Jerrican





Exploitation of a Geothermal System

200° C

250° C

300° C

Geothermal power plants tap into aquifers containing heated water. Steam is piped off to drive turbines as in a conventional power plant.

Two boreholes are drilled: one to pump the cold water down (the injection well) and another to remove the heated water (the production well). These boreholes, which terminate a few hundred metres apart, are drilled at an angle that will intercept the natural jointing in the rock.



Fissures

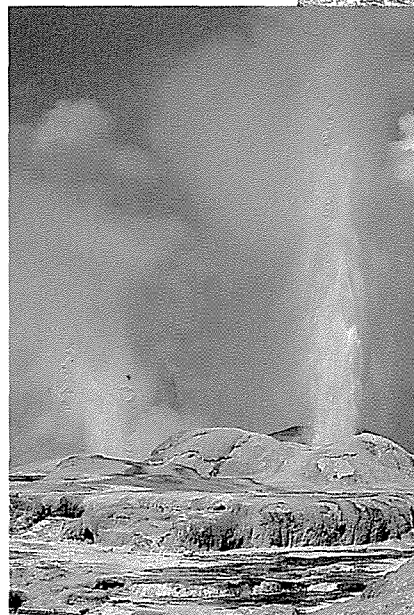
Pumping very high-pressure water between the boreholes opens up existing fissures in the rock and may also create new ones (a process known as hydrofracturing). Water is reinjected into the system to maintain a constant flow of energy.

Although this form of drilling sounds simple in theory, the technological problems it creates are

Even if geothermal water is not hot enough to generate electricity (below 150° C), it can still be used to heat houses, apartment blocks, factories and offices.



Daudier/Jerrican



Berenguer/Jerrican

evenly dispersed throughout the volume of rock. Some channels are wider than others and, as a result, cool down the rock that they come into contact with. It may soon be possible to counteract this by using chemical sealants to block off the cooler flowpaths, thus maintaining the temperature of the water being pumped to the surface.

Just amazing!

ICED BANANAS

USING GEOTHERMAL WATER TO HEAT THE GREENHOUSES, NEARLY-ARCTIC ICELAND IS ONE OF EUROPE'S MAJOR PRODUCERS OF BANANAS.

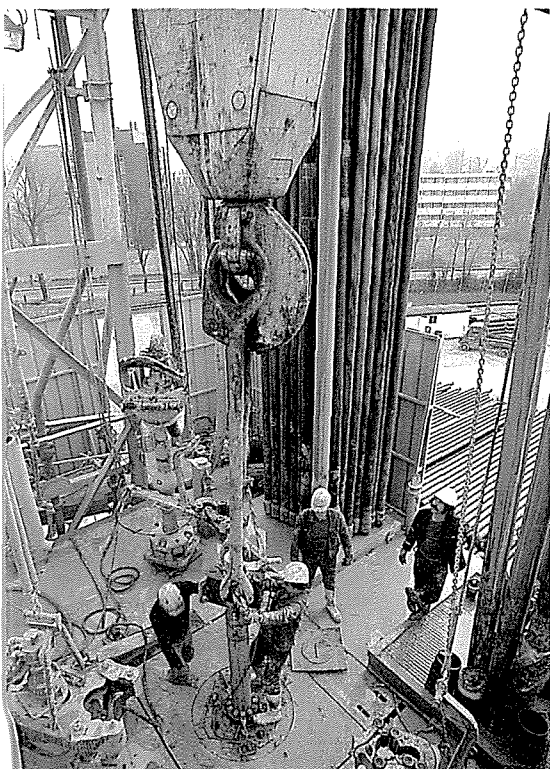


Paul Raymonde

formidable. In order to tap heat at the temperatures required for electricity generation, HDR systems must be bored in very hard rock at depths of up to seven kilometres.

Another problem facing HDR engineers is finding rock strata large enough to sustain water circulation without cooling down too rapidly. A network of fractures needs to be controlled so that water flow paths are

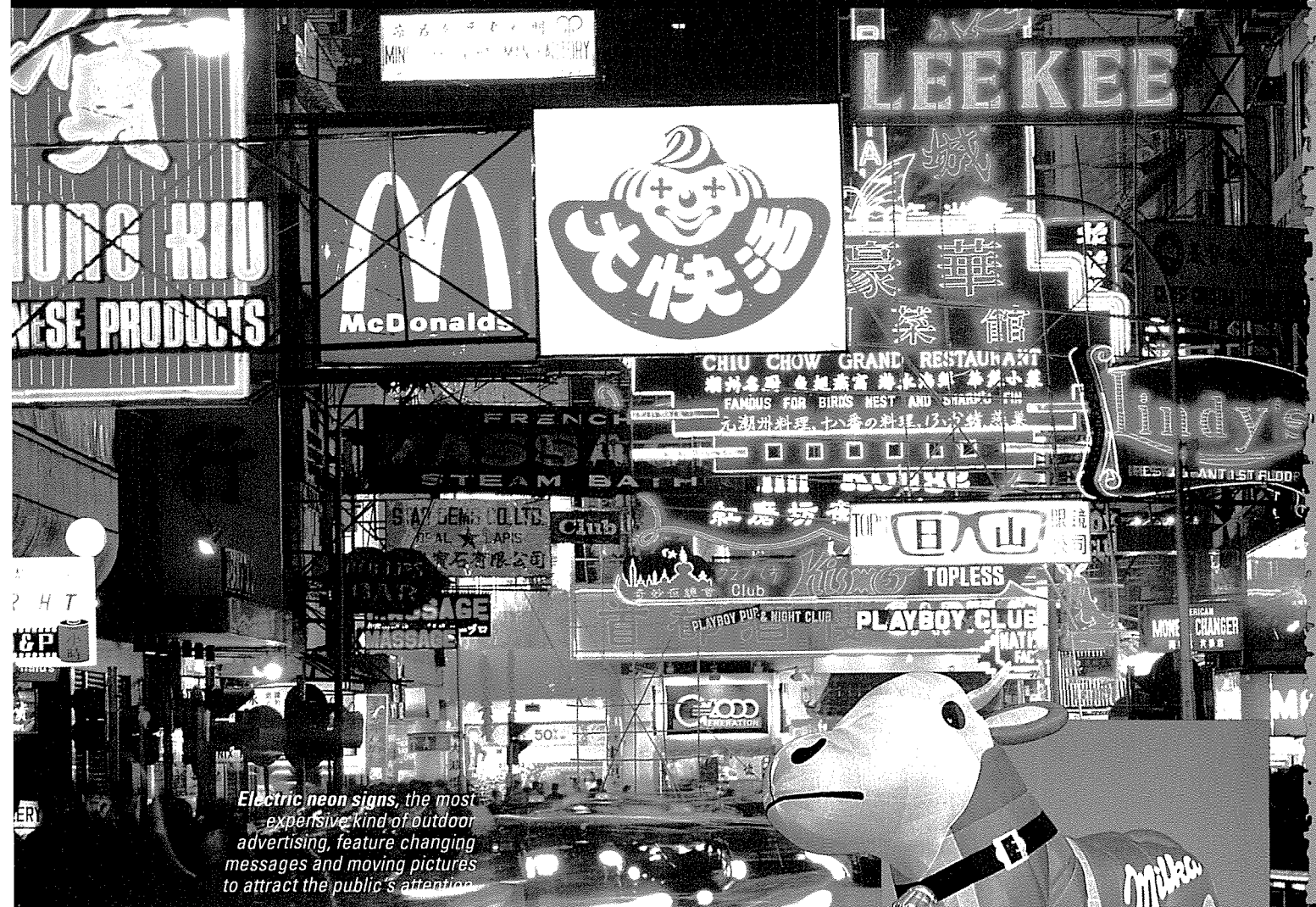
Between 10 and 20 boreholes can be drilled to tap water at a temperature of 200-300° C. In some areas, temperatures of 400° C have been measured.



Sébart/Jerrican



HARD SELL



Electric neon signs, the most expensive kind of outdoor advertising, feature changing messages and moving pictures to attract the public's attention

ADVERTISING IS A MESSAGE designed to promote a service, a product or an idea. Open a paper or magazine, walk along the high street, or simply switch on the TV or radio, and you will come into contact with many different types of advertising.

Huge advertising hoardings appear at the side of the road, posters are displayed on bus stops or even on the sides of buses themselves, neon signs flash information from buildings and commercials interrupt television and radio programmes.

The people that an advertising campaign is aimed at are known as the target group or target audience. Advertising agencies use 'quantita-

tive' and 'qualitative' research techniques, based on studies of psychology and sociology, to find out who they should be talking to, and the best way to get their message across.

Quantitative research is so called because it answers questions about numbers or quantity, such as, 'How many people buy our product?' 'How much do they buy each week?' Their answers are fed into a computer and aggregated. The people interviewed are usually asked their age and occupation, and the interviewer will make a note of what sex they are, and what part of the country they live in.

Once the market research company knows a person's occupation, they classify them according to their social grade. This method was developed

Manufacturers use many different devices for drawing attention to their products. flying over towns in a hot-air balloon is an old favourite.

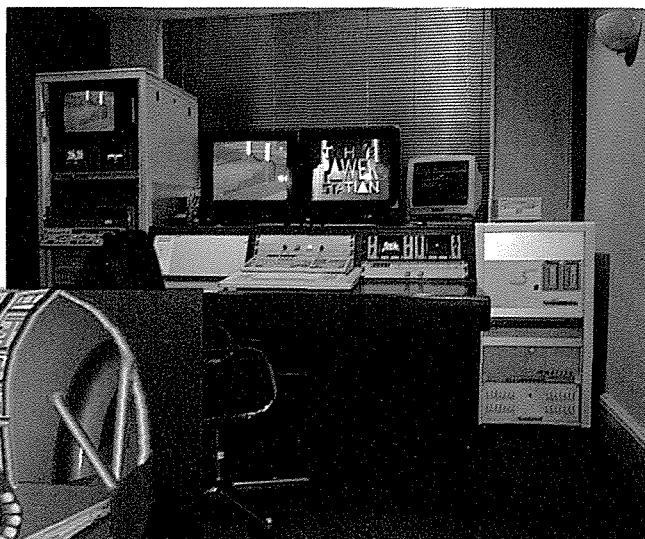


by sociologists studying the behaviour and attitudes of different social groupings. There are six social grades in the UK – A, B, C1, C2, D and E. Social grade A includes top-level managers and very senior professional people, such as judges, whereas social grade E (15 per cent of the population) is made up of pensioners and casual unskilled workers.

Most market research interviewers write the responses down on a ques-

Computerized animation
programs, such as *Matisse*, *Paintbox* and *Mirage*, have made it possible to manipulate live on-screen action, making cartoon commercials quicker and easier to produce.

Cartoon
commercials can be made on screen. The computer fills in many of the frames that were once painted by hand and turns flat 2-D images into 3-D ones (below).



answers directly into the terminal during the interview and, at the end of the day, sends the data via a modem down a telephone line to the research company's central computer.

SVC Television

The other type of market research – qualitative research – is designed to find out why people do things and how they feel about things.

Focus group

One of the best known and most widely used qualitative research techniques is the 'focus group discussion'.

The discussion group is usually made up of six or eight people, all of whom are in the target group for the product being advertised. For example, to develop an advertising campaign for a new car, the agency would carry out group discussions with the people most likely to buy a

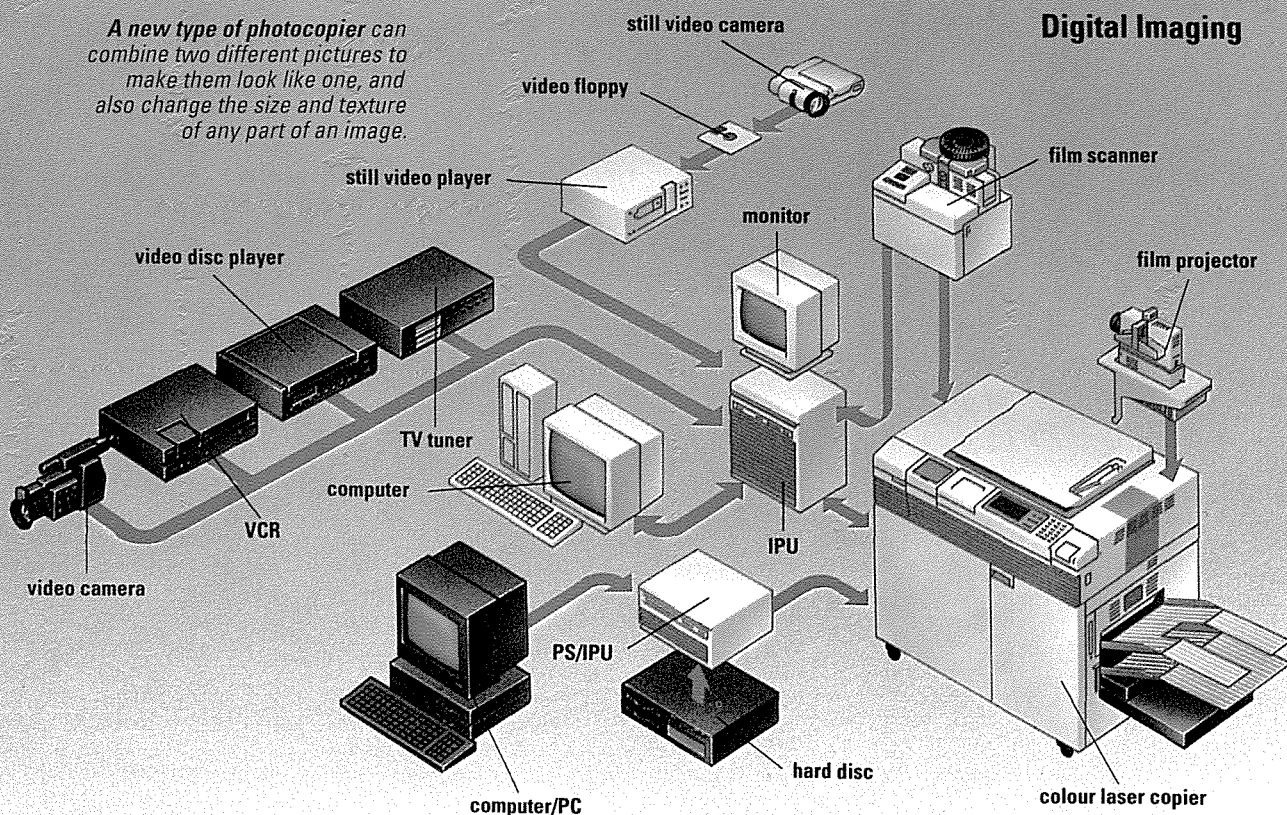
tionnaire, which is then posted back to the research company's head office for analysis. However, the whole process is going to become much faster with the development of new, hand-held computer terminals, which look like electronic personal organizers. The interviewer punches the

The Palace



A new type of photocopier can combine two different pictures to make them look like one, and also change the size and texture of any part of an image.

Digital Imaging



Canon UK Ltd/Mark Franklin



new car in the next year or so (this would probably be men, aged over 30 and social grades B or C1). The questions are disguised to make people think about the subject, rather than give 'yes' or 'no' type answers.

The amount that a television company can charge to run a typical 30-second commercial, and the amount that an advertiser is prepared to pay, depends on how many people are watching, and what sort of people they are. So it is very important for the TV companies and the advertising agencies to know who watches what. The market research company that measures TV audiences in the UK uses a panel of about 8,000 people

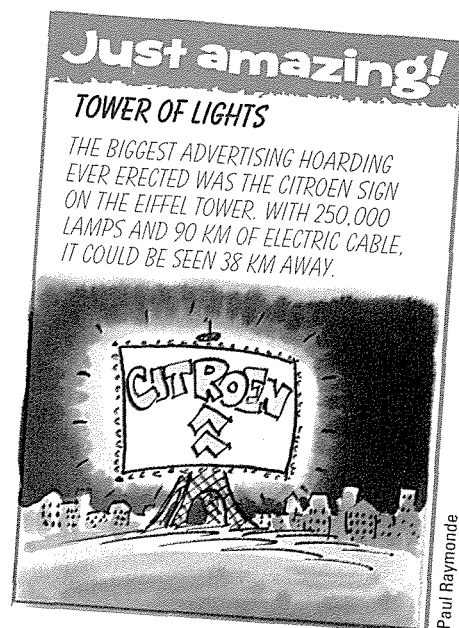
Before making a commercial, advertising agencies make a test version called an animatic, which is a very rough cartoon sketch of the action.

'black box' attached to their television set that records when it is switched on, which channel is being watched, and which channel (if any) is being video-recorded. This tells the research company how many households are tuned into any given TV programme.

Control pad

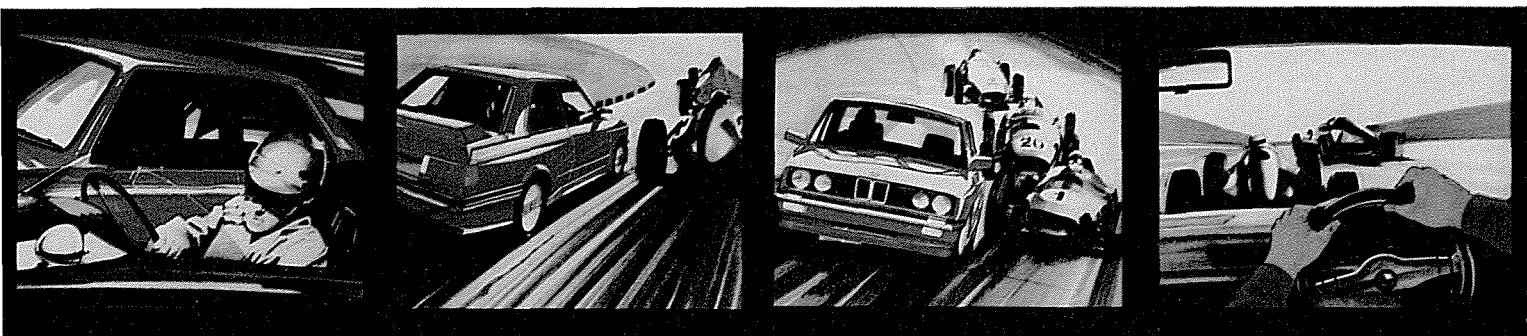
But just because a television is switched on does not necessarily mean that anyone is watching. This is why each member of the household has their own button on a control pad. This tells the black box that they have started or stopped watching. The pad also has a 'guest' button for the family to press if someone else comes round to watch television with them.

In the early hours of the morning, the research company's central computer 'telephones' every black box in the country, and the data is sent back down the telephone line. By the next



De Luxe

Paul Raymond



from 3,000 families throughout the country. They are carefully selected so that they match the population of the UK as a whole in terms of the age of both adults and children, their occupation and the region that they live in.

Each of these households has a

SPY TELEVISION

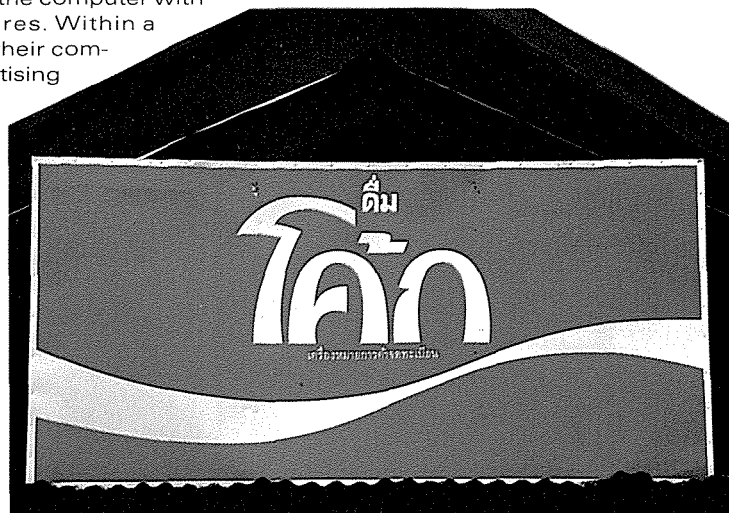
A new type of 'black box' (the device with which advertising research companies monitor viewing figures) is being developed, which will be able to watch who is watching. It will be equipped with an infrared 'eye' that can detect the presence of a living creature in the room and will also be able to distinguish the different heat patterns emitted by each member of the family. This is important because the television companies need to know what sort of person is watching and also want to ensure that the black box does not count the family dog in the viewing figures!

AGB Television

morning, the computer knows who watched what.

Over the next few days, the television stations send the details of which commercials were shown at what time of day to the research company, and this is fed into the computer with the audience figures. Within a week of showing their commercials, the advertising agencies know

Coca Cola advertisements are instantly recognizable irrespective of language (in this case Thai) because the same colours and design are used – a device used by many advertising agencies.



just how many people of each age, sex and social class in each television region saw them.

Television commercials are very expensive to produce. Some companies, such as British Airways and Coca Cola, are rumoured to have spent over £1 million on producing a single commercial.

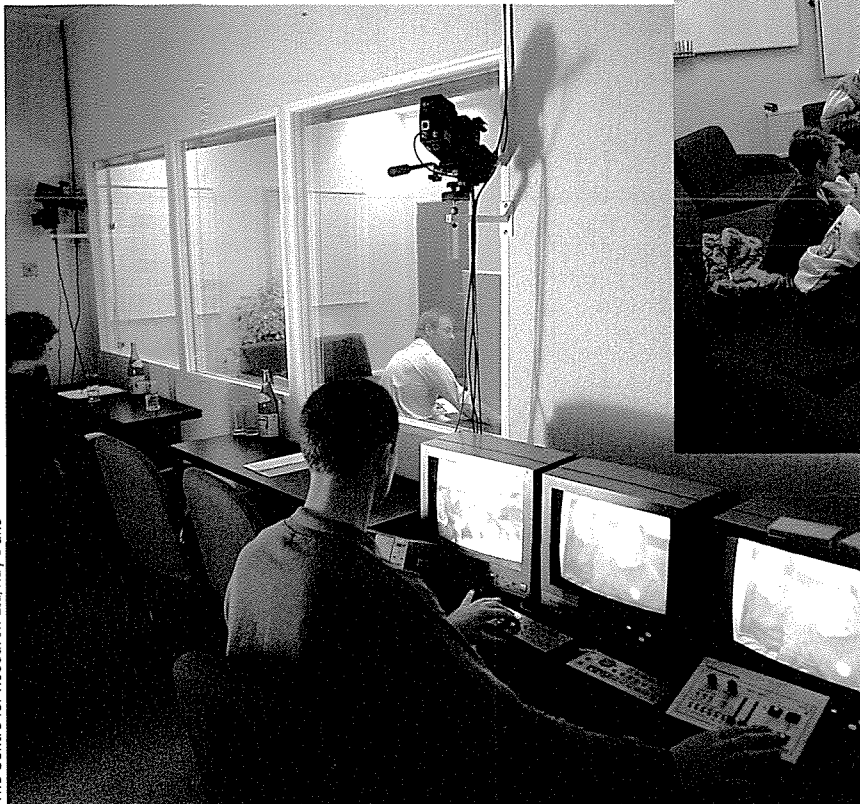
Before spending that amount of money just making a commercial, and

tested out in group discussions with typical buyers of the product concerned. The advertising agency will first make a test version, called an animatic, which is then shown to people in a number of group discussions to make sure that the commercial is making its point clearly.

Technology is making a big difference to the way TV commercials and press and poster advertisements are

Hutchison Library





Market research discussion groups are often observed from behind a one-way mirror so that the advertisers can hear the group's opinions without distracting them.

satellite channels.

Until recently, every TV company would need five or six copies of the commercial on film, which would have to be packed in film cans and sent by courier to the TV station. These days, commercials are either produced on video, or transferred on to video after they have been made on 16 or 35 mm film. Video tape is an electronic medium. This means that a commercial, pictures and sound, can be played down a land line – just like a telephone line – to the TV station.

In the near future, commercials will be sent out to stations via a microwave link, without the need for a telephone line. This works like a radio transmitter, but can send and receive pictures in sound form.

produced. One of the most exciting developments for the commercials' producers have been computer animation programs such as Harry, Paintbox, Matisse and Mirage. These have made it possible to play around with real live action and digitize the information on the screen. They can then be used to manipulate that frame, curling it up at the edges, shrinking it down into a corner, or distorting the shapes of the picture.

Today a new generation of super-photocopier, used to manipulate pictures for newspaper and magazine advertisements, can be used to record colour images digitally. Computer programs may be used to manipulate images on screen.

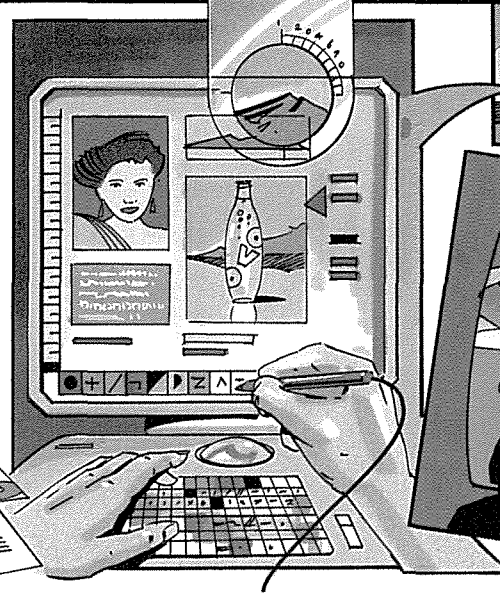
Once a TV commercial has been produced, it has to be sent to the TV station that is going to transmit it. This means sending them out to every commercial station in the country, as well as the commercial

INTO THE FUTURE

SELLING ON SCREEN



▲ TV advertising agencies will feed a client's brief into a computer terminal and produce trial visuals with the help of a Computer-Aided-Design program.



▲ An electronic image bank will provide all the visual images, which the ad producer will be able to retouch or reorientate through the CAD facility.



▲ The voice and music will be selected and synthesized by an electric voice-processor and the finished ad sent to the TV station via fibre-optic cable.

Q BOGIES

Q GUIDEWHEELS

Q AUTOMATIC TRAINS

PEOPLE RAIL

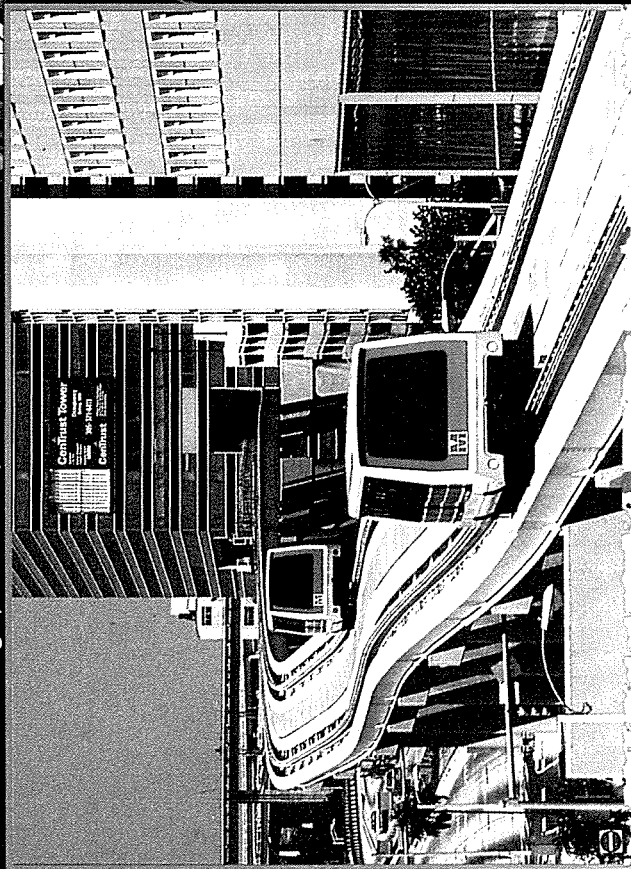
IN A FUTURE CITY PRIVATE cars might well be banned from the streets and an efficient, integrated system of metros and light rail systems will whisk citizens quickly and quietly around town.

But in many cities there is little room for additional routes and underground railways are expensive to build. So the people movers of the next century will have to be cheap and cause as little disruption as possible. Already such schemes are being built worldwide.

Light rail

One of the best known Light Rail systems in the British Isles is the 12-km Docklands Light Railway in East London. The running system is fairly

Ray Fairall/Rex Features

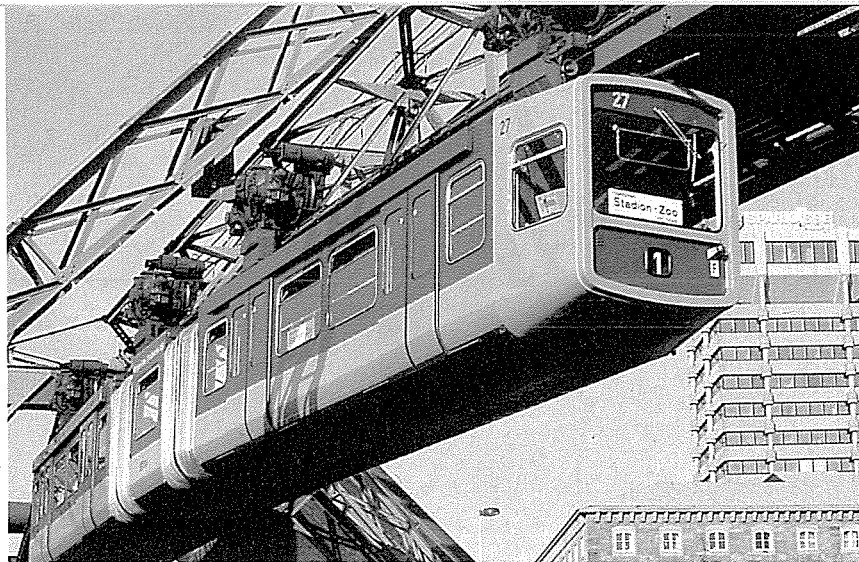


conventional, with steel wheels on steel rails, giving frequent passenger service with most of the track elevated above street level.

The Light Rail specification was chosen because it is cheaper to construct than conventional rail and uses small lightweight vehicles that can handle steep gradients and tight curves. The track therefore takes up less land and reduces the cost of

Miami's Metromover (left) began operating in 1984, while Washington DC's subway (above), plagued by teething problems, is due for completion in 2000.





structures such as bridges.

The trains are fully automatic and there are no driving cabs. There are manual controls for use in the event of partial system failure and for moving the units around in the depot.

People movers

Other people movers use elevated tracks of less conventional design. At Gatwick Airport and at Stansted Airport in the UK there are systems connecting terminals. The vehicles have rubber tyres and are electrically powered. They run on a track with a single steel guidebeam down the centre, guiding them safely along the track.

There are no on-board attendants and announcements are

In the central control room of the fully automated Metro system in Lille, France, all movements of the unmanned trains are monitored and co-ordinated.



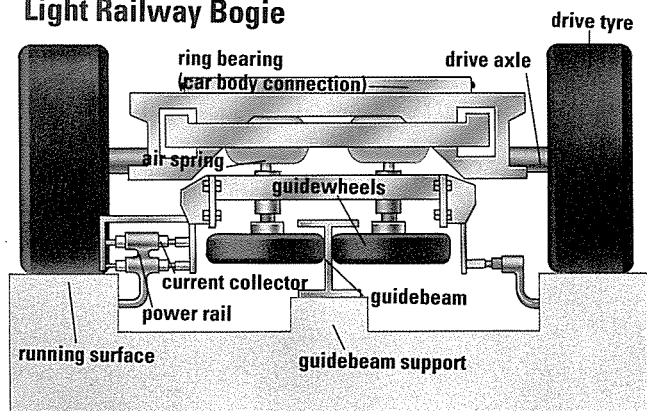
Gamma/Frank Spooner Pictures

made automatically. The passengers do not wait on platforms as such but in lobbies with their own doors that open directly on to the vehicle's own doors when it arrives. Other new metro systems, such as those in Lille, France, and Singapore have a very similar feature.

As early as 1901, Wuppertal in Germany opened its Schwebebahn or suspended railway. Having been modernized, the trains are now one-man operated.

The guidewheels lock the vehicle to the guidebeam, at the top of which are the power and signal rails.

Light Railway Bogie



Mark Franklin

the driver, while trams run on steel rails set in the roadway.

The advantages of electric power over diesel or petrol engines are that the pollution involved occurs at the power station, away from the city centre, and that electric motors can give better acceleration, do not use power when stopped, are more efficient at low speeds and do not need heavy, bulky gearboxes.

Dual systems

The snag is that it is costly to set up overhead wires over an extensive system serving suburbs. So in Essen, Germany, and Adelaide, Australia, there are dual-mode guided trolley-

buses. These run using electric power in special concrete guided tracks in the city centre, but in the suburbs their diesel engines take over and they can collect passengers over a wide area. Currently in Essen, 6 km of guided busway are in operation, partly running underground.

New tram systems have recently been completed in several cities, including Manchester and Sheffield in the UK, and others are planned. Trams have the advantage that several units can be joined together under the control of one driver. They can travel on street tracks and on existing rail tracks.

Elevated track can be difficult to build in crowded streets, so some cities are bringing back trolleybuses and trams, popular in the first part of the 20th century.

Both collect electric power from overhead wires. Trolleybuses run on conventional tyres and are steered by

Maintenance is a matter of course with the new people mover systems. At Atlanta's Hartsfield International Airport, points on the line automatically guide the trains into the maintenance area, where a number of vehicles can be serviced simultaneously.



Just amazing!

CHINESE TAKEAWAY

HANDLING 2,552 MILLION PASSENGERS A YEAR, THE MOSCOW UNDERGROUND CAN MOVE TWICE THE POPULATION OF CHINA.



Paul Raymonde

- ☐ DROUGHT
- ☐ MALNUTRITION
- ☐ GLOBAL WARMING

FAMINE

SEVERE DROUGHTS IN Southern Africa in the 1990s added to the devastation already caused by famine in the Horn of Africa and the Sahel, which were hit by prolonged droughts in the 1970s and 1980s. Yet massive mountains of food collected in European warehouses and over-production caused collapses in the price of grain.

So why is it that millions of people in this world starve to death when there is plenty of food to go round?

Cash crops

The problem is that the countries where people starve are poor. To develop their economies, governments in developing countries encourage the growing of cash crops, such

J. Hartley/Panos Pictures



Seasonal rains in many regions, particularly along the southern border of the Sahara, are no longer dependable and drought may persist for years.

as coffee, cotton, groundnuts and tea, which can be sold to rich countries. The money they receive is not enough to develop their countries. Some is used to buy tractors and fertilizer. Some of it goes on improving roads and railways. In some countries much of the money is used to equip armies and to pay interest on money borrowed from banks.

As more fertile land is turned over to more cash crops, there is less room to grow the staple foods local people need to survive. The poorer people get squeezed out and are forced to

Sarah Errington/Hutchison Library



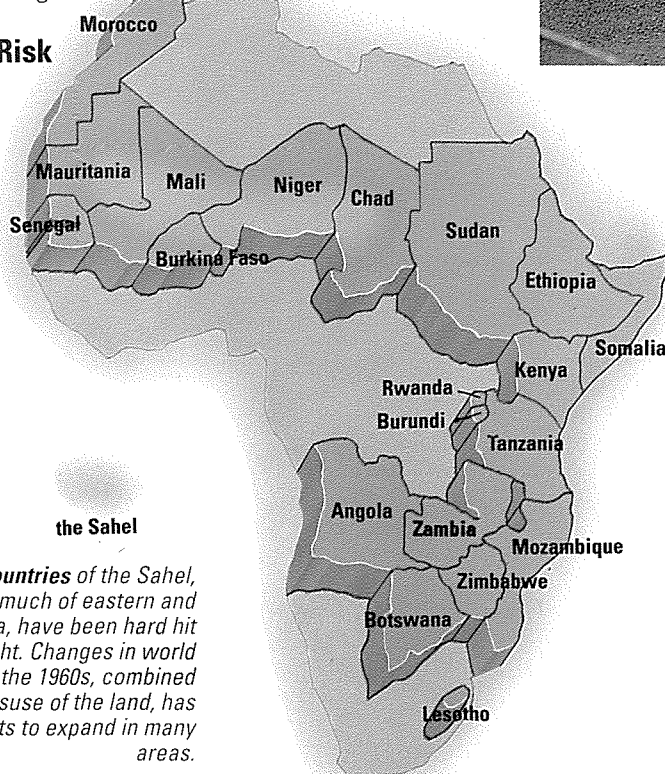
move on to poorer land which is more vulnerable. When a drought hits, they sell their cattle to buy grain. However, with the prospect of famine on the horizon, the price of grain rises, so the poor people can only buy a little of it. If they do not eat it all right away and save some to plant, they find the ground too dry for it to grow. Within a few months, poor people find themselves without food and with their entire savings wiped out.

Most of the famine areas of the world are almost without exception in poor countries south of a line drawn through the

The transportation of food aid is not always straightforward. Storage facilities at ports and transport networks overland are often inadequate. Civil war, bureaucracy and corruption among officials also hamper relief operations.



Africa at Risk



the Sahel

The countries of the Sahel, together with much of eastern and southern Africa, have been hard hit by drought. Changes in world climate since the 1960s, combined with human misuse of the land, has caused deserts to expand in many areas.

WHAT CAN BE DONE TO AVOID FAMINE?



Famine is an economic problem rather than a technical one. Currently, the poorer countries in the world are burdened with crippling debts. Somehow a way must be found to write off these loans.

Land reforms have to be introduced to prevent poor people being forced into infertile areas where they have no chance to feed themselves adequately.

New high-yield varieties of maize and wheat must be introduced. Irrigation schemes must be introduced to make margin land more productive.

Farmers must be encouraged to develop skills which will make them less dependent on food they cannot grow themselves.

Mediterranean, particularly in Africa. Bad roads in these regions make it difficult to send food supplies in. War also rages in some of the famine areas. Food convoys are often denied access to war zones and armies take food aid to feed their troops – or to try to starve out the opposition.

When food aid does arrive, it can cause problems too. Large volumes of imported wheat, for instance, can lower the price of grain, discouraging local farmers from growing more food. Many relief agencies believe that helping people to grow or earn their own food is much more effective

than sending them grain mountains.

Other factors can make certain areas vulnerable to famine if the rains fail. The ploughing of pasture land to grow cash crops, for example, leaves herdsmen nowhere to graze their cattle – which is the best way to make use of poorly watered land. Grains also deplete the nitrogen in the soil so, unless fertilizer is added or crops are rotated, the land can quickly become unproductive.

Life on the edge

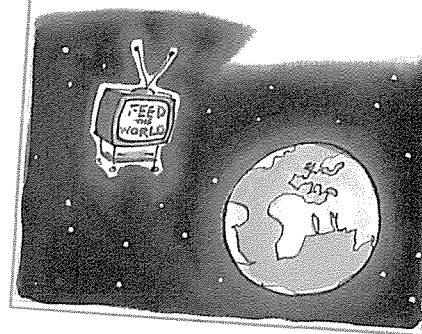
In many parts of the developing world the average diet is insufficient to preserve the standards of life and health that are taken for granted in the West. People who do not get enough to eat cannot work well, so they have problems earning enough money to buy food or growing enough to feed themselves. And when drought hits and food gets more expensive and harder to grow or forage for, these people do not have the strength to work any harder.

People who are undernourished are more vulnerable to disease. And people with diseases – especially those that lead to diarrhoea – need more food. It is a vicious cycle.

Just amazing!

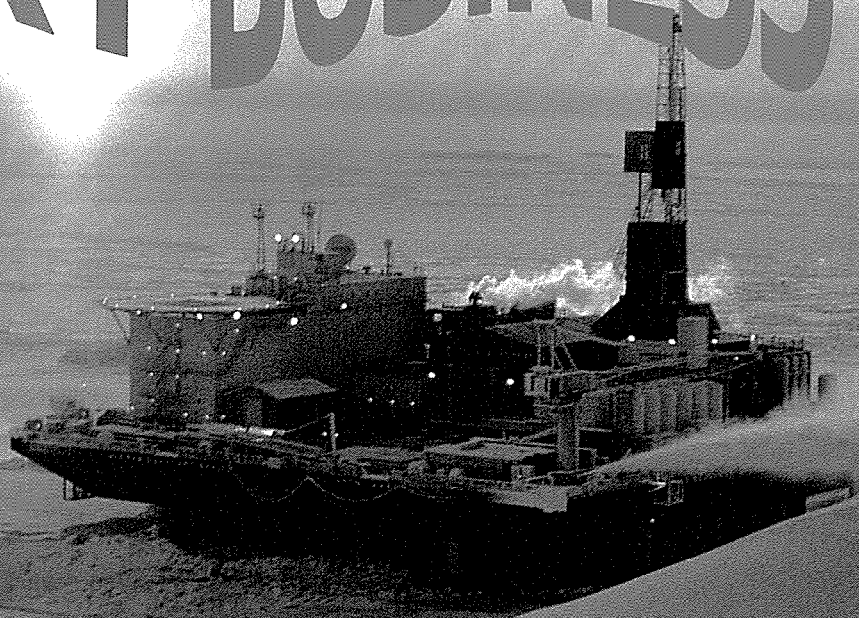
FEEDING THE WORLD

THE TV AUDIENCE FOR 'LIVE AID' – THE CONCERT RUN BY BOB GELDOF TO HELP THE STARVING OF ETHIOPIA IN 1985 WAS 1.6 BILLION, NEARLY A THIRD OF THE WORLD'S POPULATION.



RISKY BUSINESS

Mark Green/Tony Stone Photo Library, London



Drilling for oil on offshore rigs is statistically one of the most dangerous occupations. In 1988, 167 men died in a fire on the Piper Alpha rig in the North Sea.



Robert Frerck/Tony Stone Photo Library, London

LIFE IS DANGEROUS.

It inevitably results in death. Nothing you can do – eating, breathing, walking down the street – is completely safe. But some things are more dangerous than others. Sliding down Mount Everest on a tea tray is more dangerous than staying at home with the curtains drawn.

Nuclear power stations are thought of as dangerous. There are also risks involved in the mining, transport and use of nuclear fuels. But then there are risks involved in the generation of electricity from any known source.

mines, the uranium ore is mixed with a lot of rock and is in such small quantities that it is hardly dangerous at all. But this means that much more material has to be shifted to get one tonne of uranium than one tonne of coal.

However, you need 18 tonnes of coal to give you the same amount of electricity as just one kilogram of uranium. For the same amount of electricity more than 13 times as many coal miners are killed in mining accidents as uranium miners.

This underestimates the risk to uranium miners because there is also a long-term risk of developing cancer from handling uranium ore. But in fact,

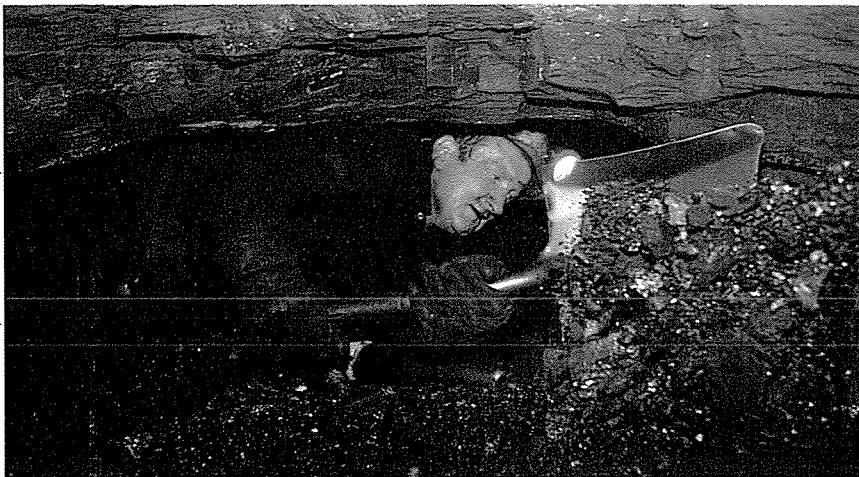
the radioactive gas radon found in uranium mines is much more dangerous than the ore itself. However, with proper ventilation even that danger can be reduced to the levels of radioactivity that you would sometimes find in a building made of brick and stone – even a harmless looking household brick contains some radioactive material.

Black lung

The disease pneumoconiosis is caused by inhaling the rock dust generated in mining. But black lung – a condition caused by inhaling coal dust – is much more dangerous. Drilling for oil, especially in the North Sea, is even more hazardous.

There are also dangers associated with the transportation of fuels. Coal is usually transported by rail, which is remarkably safe. Uranium ores also have to be transported – but much





Mining coal ranks only below deep-sea fishing as a high-risk occupation.

rail. So far there have been no serious accidents transporting nuclear fuel. Meanwhile some 12 people are killed every year in Britain by tankers transporting oil by road.

Radiation risk

In Britain, in ten years, 32 people were killed in coal-fired power stations. During the same period two people were killed in a nuclear station – neither from radiation – and one was killed in an oil-fired station. This is hardly surprising as there are many more

IS FOOD SAFE?

The safety of food is constantly monitored. Food additives to colour or preserve food are usually added in quantities of 100 or 200 parts per million. If a new substance is used it is first fed in increasing quantities to laboratory rats – until they die. New rats are then fed with the maximum non-fatal dose of the substance for two years and the side effects studied. A maximum tolerable dose per kilogram body weight is then worked out. An acceptable daily intake is then calculated by dividing by a safety factor of 100 – 10 to take account of the difference between a human's metabolism and a rat's, and 10 to take account of the differences between humans.

Scientists then work out how much of a substance a human being will take in, in the worst possible case – if they have a special diet and eat the same thing for every meal every day. The maximum possible intake must be below the acceptable daily intake before the additive is licensed for use.

Scientists keep an eye on the level of pesticides, chemicals migrating from packaging and new types of food in the same way.

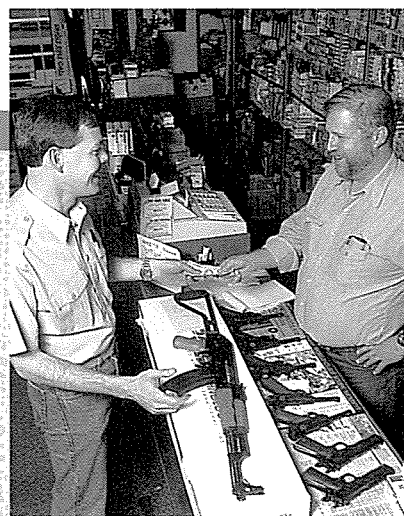
HOME SWEET HOME

The outside world is a dangerous place, so why not stay safe at home? Only staying at home is not safe at all. Falls kill more people than anything except traffic accidents, and most falls happen at home. Most deaths from burning happen at home, too. With increased insulation the air at home is likely to be more polluted than the air outside.

The average modern house is full of high energy appliances that can wound by cutting, ripping, puncturing and hitting the human body. You risk being electrocuted by electrical appliances and scalded by hot water. Boiling water from kettles and stoves are particularly dangerous. Poor housing greatly increases the risk of premature deaths. And in countries like the USA, where guns are commonplace, more people get shot at home as the result of domestic arguments than as a result of crime in the streets.

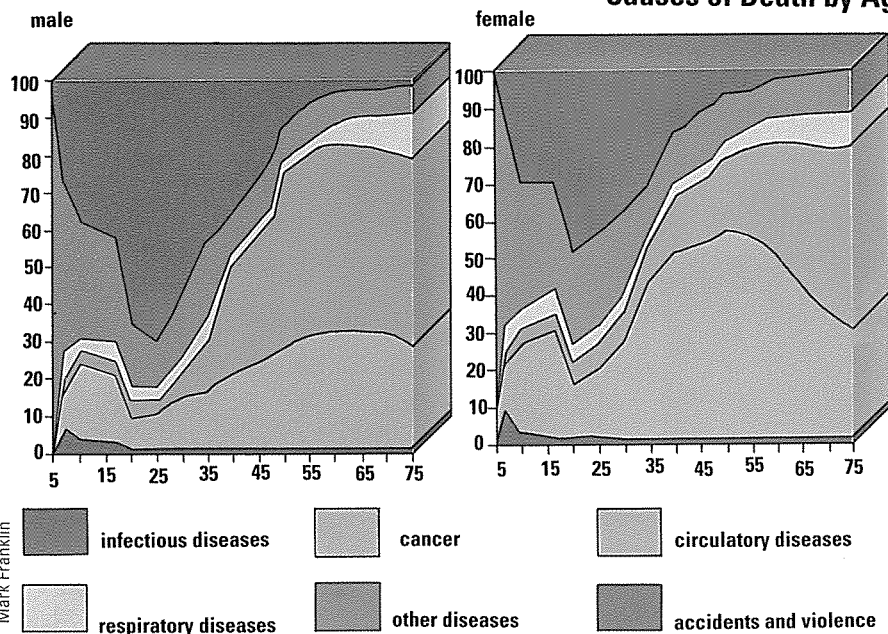
coal-fired power stations in Britain and such figures only take account of accidents, not the long-term risks of being exposed to radiation.

Just having nuclear power stations around is dangerous, though. Some tiny amounts of radiation do escape into the surrounding environment. Near the nuclear reprocessing plant at



A. Weiner/Gamma/FSP

Causes of Death by Age



Causes of death for males and females in 1986. The tables show the varying susceptibility of men and women to different diseases according to age.

Sellafield in Britain, four cases of childhood leukaemia – which can be caused by radiation – were detected in 30 years. However, this was just the same number that would have been expected normally.

Around Britain small nests of higher-than-expected incidents of leukaemia have been discovered. There are over 500 of these nests, considerably more than the number of nuclear power stations in the UK. Often, though, they are associated with areas where the radioactive gas radon occurs naturally. So far no deaths have been directly related to

the slight increase in radioactivity caused by discharging water used for cooling into rivers and the sea.

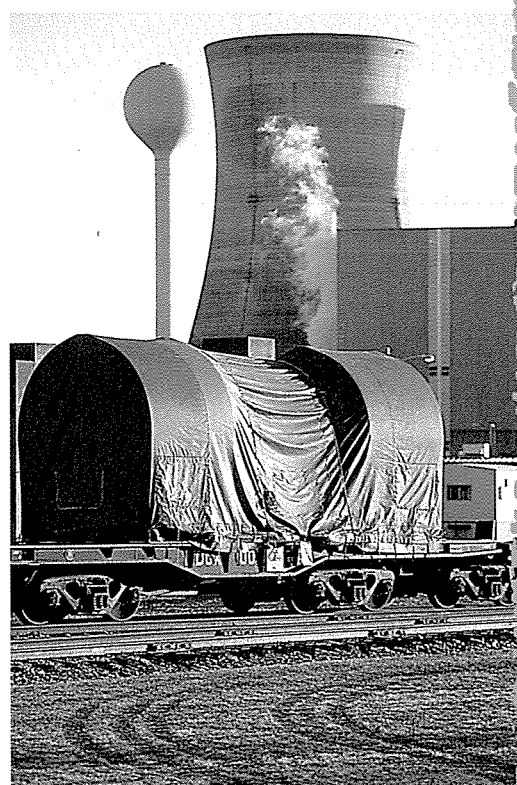
Nuclear waste is known as tailings. When these are buried the extra risk to the public is essentially zero – after all, uranium mining does not create radioactivity so burying radioactive material is simply returning it to where it came from.

If the tailings are not buried, radon gas leaks out. In that case, it is estimated that the risk is equal to one fatal cancer case for every ten years of operation.

Acid rain

Coal- and oil-fired power stations have other problems. They pump huge amounts of pollution into the atmosphere. Sulphur dioxide and nitrous oxides cause acid rain. Carbon dioxide contributes to the greenhouse effect. Coal and oil burning also causes smog. Before coal burning was banned in London some 3,500 to 4,000 people died as a result of smog in just five days.

However, what people are really afraid of is a nuclear accident like the one at Chernobyl in the USSR in April 1986. Operators deliberately turned off the safety devices to test a turbine. The cooling water boiled. The power generated by the core shot up uncontrollably and the resulting explosion blew the containment building wide open.



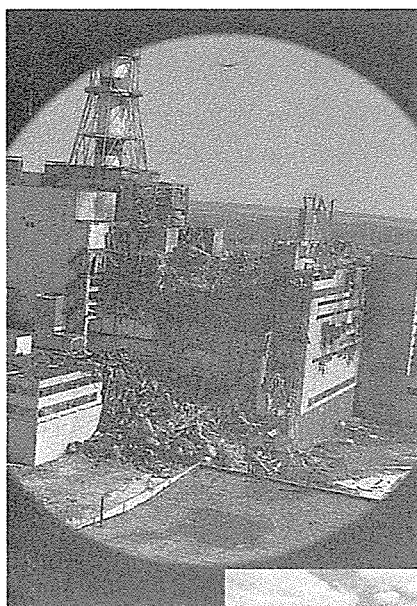
Nuclear waste debris waiting to be transported by rail from the Three Mile Island nuclear plant in Pennsylvania, USA.

Alexander Tsirlas/SPL

dence of leukaemia was also rising.

By 1992, the Ukrainian government estimated that over 6,000 people had already died and that the death toll in Ukraine alone may reach 40,000. Other estimates suggest that the accident will cause 1,000 extra cancer deaths in western Europe and 1,250 in eastern Europe.

But this is minute compared with the number of cancer deaths altogether. In the UK, Chernobyl will cause around 35 extra cancer deaths in the next 50 years. During that time over seven million people in the UK will have died of cancer.



SIPA/Rex Features

Background radiation in Britain was increased by roughly 3 per cent after the explosion at Chernobyl nuclear plant.



Novosti/Gamma/FSP

FEAR OF FLYING

Flying by aeroplane is often thought of as dangerous. In fact, you are more than ten times as likely to be killed travelling the same distance by car, 100 times as likely to be killed travelling the same distance on a bicycle and 200 times as likely to be killed on a motorbike. Even walking has its risks. Travelling the same distance on foot is, statistically, 188 times as dangerous.

Some of the firefighters were affected by radiation sickness. By the end of 1986, 30 were dead and 200 more were receiving medical care. About 135,000 people were evacuated from the surrounding area. By 1992, seven times as many children in Belarus and Ukraine were contracting thyroid cancer as before the accident. The inci-



Rex Features

Just amazing!

YELLOW MAN

ANYTHING CAN KILL IF YOU EAT ENOUGH OF IT. RECENTLY AN ENGLISHMAN DRANK HIMSELF TO DEATH WITH CARROT JUICE. HE TURNED YELLOW FIRST.



Paul Raymond

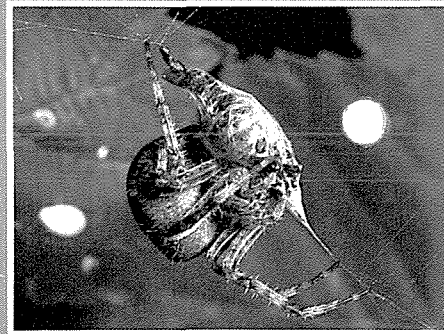
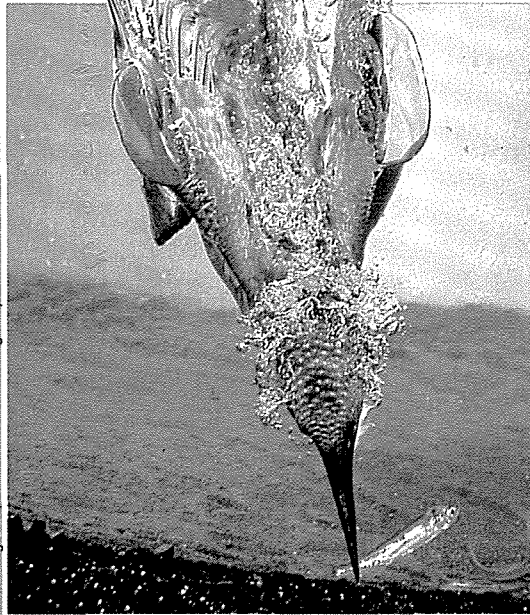


J. Scott/Planet Earth Pictures

A lioness killing a wildebeest – its favourite prey. Two methods of killing are breaking the prey's back with the front paws and biting its throat.

The kingfisher catches its prey in a swooping dive. It will beat the fish against its perch to flatten any spines before swallowing the fish head first.

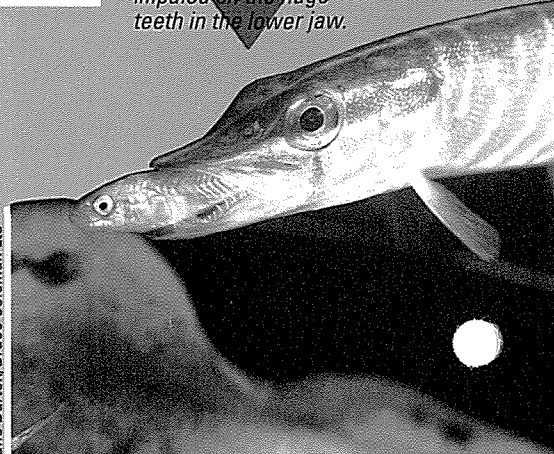
F. Polking GDT/Frank Lane Picture Agency



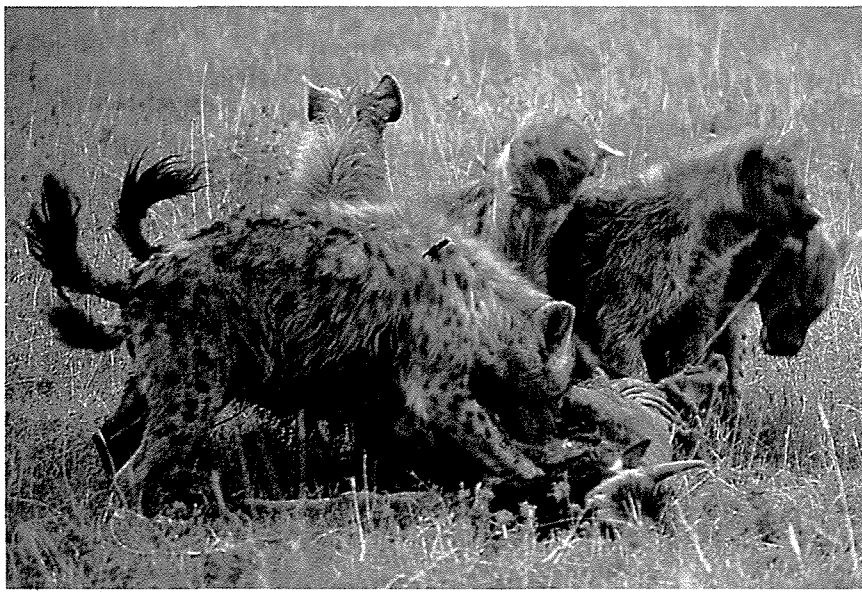
A female garden spider feeding on a wasp encased in its web of silk threads.

Martin Dohm/SPL

A pike, the most voracious freshwater fish, with its prey impaled on the huge teeth in the lower jaw.



Gunter Ziesler/Bruce Coleman Ltd

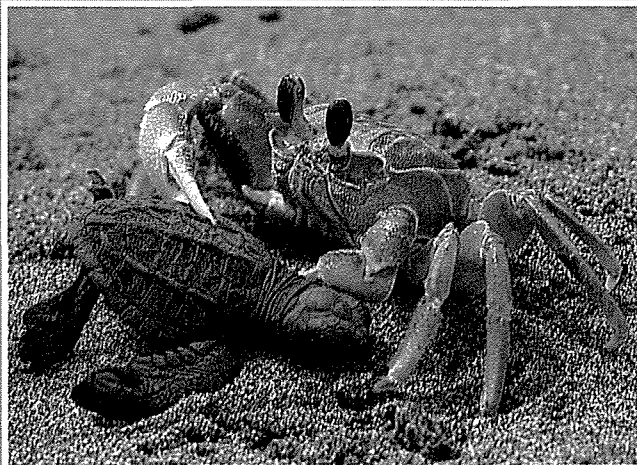


Spotted hyenas devouring a young wildebeest. Hyenas are scavengers as well as predators. Their teeth can cut skin and gristle and crush bones.

C. Prior/Planet Earth Pictures

This ridley turtle hatchling failed to reach the ocean at Nancite beach, Costa Rica. In its young, vulnerable state it has no defence against the ghost crab.

C. Hughes/Bruce Coleman Ltd



The jaws of a snake are specially adapted to allow the huge gape needed to swallow a frog. The lower jaw is divided and loosely connected.

A praying mantis using its forelegs with sharp hooks to hold the butterfly that it will eat alive. The female mantis will eat its own mate if hungry.

G. Du Feu/Planet Earth Pictures

